Plant Caretaker: A Virtual Reality Experience for Mindful Plant Care and Stress Reduction

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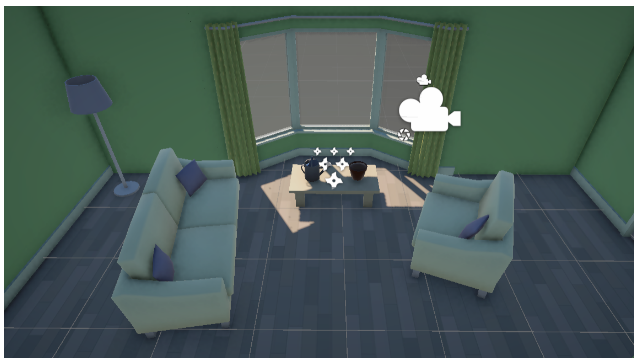


Abstract

In an era of ecological crisis and digital acceleration, I present "Plant Caretaker," a virtual reality experience that explores the therapeutic potential of mindful plant care. This first-person VR application, developed for the Meta Quest 3 using Unity and Meta XR SDK, places users in an ambiguous environment where they must tend to a randomized plant species without explicit instructions. The system incorporates realistic plant care mechanics including watering, lighting management, and tactile interaction, coupled with non-linear temporal dynamics and subtle environmental feedback. Through user studies with 10 participants, I demonstrate significant improvements in mood and stress levels following 15-minute sessions. My approach challenges traditional VR design paradigms by embracing uncertainty, failure, and slow-paced interaction as therapeutic elements. The system contributes to the growing field of nature-based VR therapy while offering insights into designing meaningful human-plant relationships in virtual environments.

1. Introduction

The therapeutic benefits of interacting with nature have been well-documented in environmental psychology literature, with activities such as gardening and plant care showing measurable impacts on mental health and well-being [2]. However, urbanization, mobility constraints, and lifestyle factors often limit access to meaningful nature-based activities. Virtual Reality (VR) has emerged as a promising medium for delivering nature-based therapeutic experiences, offering controlled environments that can be accessed regardless of physical limitations or geographic location.

This paper presents "Plant Caretaker," a VR experience that explores the intersection of digital technology and mindful plant care. Unlike conventional VR applications that prioritize clear objectives and immediate feedback, this new system deliberately incorporates ambiguity, uncertainty, and non-linear progression to mirror the authentic challenges and rewards of real-world plant caregiving.

My primary contributions include: (1) a novel VR plant care simulation that integrates realistic botanical mechanics with therapeutic design principles, (2) an evaluation framework for measuring mood and stress impacts of nature-based VR experiences, and (3) insights into designing meaningful uncertainty and failure states in therapeutic VR applications.

The system addresses the growing need for accessible stress-reduction interventions while challenging traditional assumptions about user experience design in virtual environments. By embracing rather than eliminating confusion and ambiguity, we create space for reflection, experimentation, and authentic emotional engagement with virtual nature.

2. Related Work

My work builds upon interdisciplinary research spanning VR therapy, nature-based interventions, and human-computer interaction design for well-being.

2.1. Virtual Nature and Mental Health

Lin et al. [1] demonstrated significant improvements in physical and mental health among institutionalized older adults who participated in combined 3D VR and hands-on horticultural therapy sessions. Their findings showed measurable reductions in depression and anxiety levels, supporting the integration of immersive nature experiences in therapeutic settings.

White et al. [2] provided a comprehensive review of virtual nature applications in healthcare, highlighting the potential for VR-based nature exposure to serve as a valuable substitute for real nature contact, particularly for individuals with mobility constraints or limited access to natural environments. Their work establishes the theoretical foundation for virtual nature as a legitimate therapeutic intervention.

Chan et al. [3] examined virtual forest experiences across age groups, finding that virtual nature exposure reduced negative affect and stress while enhancing feelings of nature connectedness. This research validates the cross-generational appeal and effectiveness of VR nature experiences.

2.2. Plant Care and Well-being

Horticultural therapy research has consistently demonstrated the psychological benefits of plant care activities, including reduced cortisol levels, improved mood, and enhanced sense of purpose and responsibility. These findings informed my decision to focus specifically on plant care rather than passive nature observation.

2.3. Uncertainty and Ambiguity in Design

Drawing from feminist technology studies and critical design theory, my work challenges the conventional VR design emphasis on clarity and control. Instead, I position uncertainty and disorientation as potentially valuable elements that can foster deeper engagement and reflection.

3. System Design and Implementation

3.1. Core Architecture

Plant Caretaker is implemented in Unity 6 using OpenXR and the Meta XR SDK (Version 76) with compatibility for controller and pass-through hands interactions. The system runs on Meta Quest 3 headsets and consists of several interconnected subsystems managing plant health, environmental dynamics, and user interaction.

The core architecture revolves around the PlantHealth class, which serves as the central hub for all plant-related systems:

Listing 1. Beginning of PlantHealth.cs

```
public class PlantHealth : MonoBehaviour
{
    [Header("Health Settings")]
    [Range(0f, 100f)] public float health = 100f;

    public float maxHealth = 100f;
    public float minHealth = 0f;

    [Header("Growth Settings")]
    public bool enableGrowth = true;
    public float baseGrowthRate = 0.02f;
    public int maxGrowthStage = 3;
    public int currentGrowthStage = 1;

    [Header("Growth Requirements")]
    [Range(0f, 1f)] public float growthHealthThreshold=0.8f;

    public float timeInOptimalConditions = 0f;
    public float requiredOptimalTime = 30f;

    // Component references
    private PlantWatering wateringSystem;
    private PlantSunlight sunlightSystem;
    private PlantTouch touchSystem;
}
```

3.2. Plant Care Mechanics

The system models three primary care variables: water level, sunlight exposure, and tactile interaction. Each plant is randomly assigned one of three species archetypes (drought-resistant, normal, or water-loving) with corresponding optimal care ranges, though these specifications are not communicated to users. The health calculation system weighs multiple environmental factors:

Listing 2. CalculateOverallHealth() Function in PlantHealth.cs

```
private void CalculateOverallHealth()
{
    float healthChange = -0.03f * Time.deltaTime;

    float waterFactor = EvaluateWaterFactor();
    float sunlightFactor = EvaluateSunlightFactor();
    float touchFactor = EvaluateTouchFactor();

    float totalWeight = sunlightWeight + waterWeight + touchWeight;
    if (totalWeight > 0)
    {
        float normalizedSunWeight = sunlightWeight / totalWeight;
        float normalizedWaterWeight = waterWeight / totalWeight;
        float normalizedTouchWeight = touchWeight / totalWeight;

        healthChange = (
            (sunlightFactor * normalizedSunWeight) +
            (waterFactor * normalizedWaterWeight) +
            (touchFactor * normalizedTouchWeight)
        ) * Time.deltaTime;
    }

    health = Mathf.Clamp(health+healthChange, minHealth, maxHealth);
}
```

3.2.1 Watering System

The watering mechanics utilize Unity's particle system to simulate realistic water physics. The WateringCanController class monitors the tilt angle of a virtual watering can, triggering particle emission when the angle exceeds 45 degrees. Water particles that collide with the plant increase its water level according to configurable rates, while evaporation occurs continuously at species-specific rates.

Listing 3. Particle-Based Water Detection

```
void OnParticleCollision(GameObject other)
{
```

```
    if (other.CompareTag("WaterParticles"))
    {
        waterLevel += waterPerParticle;
        waterLevel = Mathf.Clamp(waterLevel,
                                  minWaterLevel,
                                  maxWaterLevel);
    }
}
```

Water evaporation occurs continuously at species-specific rates, typically 2% per second for normal plants, creating a dynamic equilibrium that requires regular attention.

3.2.2 Lighting Dynamics

A dynamic day-night cycle affects plant sunlight exposure through the DayNightCycle class, which manages directional lighting, skybox transitions, and shadow calculations. Sunlight intensity follows a configurable animation curve, with plants receiving varying exposure based on their position relative to light sources and environmental occlusion.

Day-Night Cycle Implementation

The lighting system operates on accelerated timescales with configurable day duration (default 360 seconds). Sunlight intensity follows a mathematical curve based on time of day:

$$I_{sun}(t) = \begin{cases} 0 & \text{if } t < 0.25 \text{ or } t > 0.75 \\ C_{curve}(1 - |2(t - 0.5)| \cdot 2) & \text{if } 0.25 \leq t \leq 0.75 \end{cases} \quad (1)$$

Where t represents normalized time of day (0-1) and C_{curve} is a configurable animation curve for smooth transitions.

Occlusion and Shadow Calculation

Plants receive differential sunlight exposure based on their position relative to light sources and environmental geometry. The system uses raycasting to determine shadow occlusion:

Listing 4. Shadow Detection Algorithm

```
private bool IsPlantInDirectSunlight(PlantSunlight plant)
{
    Vector3 rayDirection=directionalLight.transform.forward;
    RaycastHit hit;

    if (Physics.Raycast(plant.transform.position,
                        -rayDirection,
                        out hit))
    {
        return hit.transform == plant.transform;
    }
    return true;
}
```

3.2.3 Touch Interaction

The PlantTouch system detects physical contact through collision detection, applying species-specific responses to tactile stimulation. Some plants benefit from touch while others experience stress, creating opportunities for users to discover individual plant preferences through experimentation.

Listing 5. Touch Response Mechanism

```
public void Touch(float intensity = 20f)
{
    touchIntensity = Mathf.Min(touchIntensity + intensity,
                               maxTouchIntensity);

    // Apply health effect based on plant preference
    float healthChange = healthImpactRate*Time.deltaTime*
                         (touchIntensity/maxTouchIntensity);

    if (likesBeeingTouched)
        plantHealth.IncreaseHealth(healthChange);
    else
        plantHealth.DecreaseHealth(healthChange);
}
```

3.3. Temporal Disorientation

3.3.1 Non-Linear Time Progression

To challenge conventional optimization strategies, the day-night cycle operates on variable and accelerated timescales. This prevents users from developing routine-based approaches and encourages present-moment attention to environmental cues.

3.3.2 Unpredictable Growth Patterns

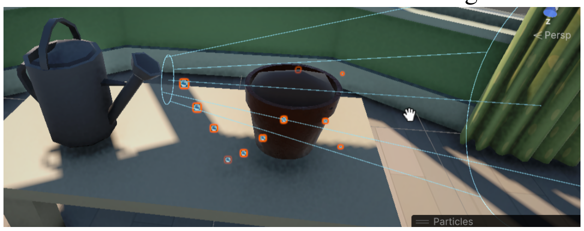
Plant development follows non-deterministic patterns where optimal conditions must be sustained rather than achieved momentarily. The system resets progress timers whenever conditions become suboptimal, preventing exploitation of brief favorable periods.

3.4. Environmental Feedback

Rather than explicit UI indicators, the system communicates plant state through environmental changes. This approach maintains immersion while requiring users to develop sensitivity to non-verbal plant communication.

- **Material Changes**: Healthy plants use bright materials, stressed plants display darker, wilted appearances

- **Particle Effects**: Water particles provide immediate visual feedback for watering actions



- **Scale Transformations**: Touch-responsive plants exhibit subtle size changes based on stimulation levels
- **Color Transitions**: Plant materials shift between healthy, stressed, and unhealthy color palettes

3.5. Performance Optimization

The system implements several optimization strategies for VR performance:

- **Condition Checking**: Growth evaluations occur at 1-second intervals rather than per-frame
- **Debug Limiting**: Console output is throttled to prevent performance degradation
- **Component Caching**: System references are cached at initialization to avoid runtime lookups
- **Efficient Raycasting**: Shadow calculations use single-ray tests with early termination

3.6. Modularity and Extensibility

The component-based architecture allows for easy extension:

- New plant species can be added by adjusting optimal parameter ranges
- Additional environmental factors can be integrated through the weighted health system
- Visual feedback systems can be enhanced without affecting core mechanics
- Multiple plant management scales naturally through the modular design

4. User Study and Evaluation

4.1. Methodology

I conducted a study with 11 total participants recruited from university populations. Each participant completed a self-paced Plant Caretaker VR session with physiological and subjective stress measurements collected before, during, and after the experience.

4.1.1 Quantitative Measures

Physiological Data: - Heart rate (BPM) measured continuously using pulse oximeter - Three measurement points: pre-session baseline, mid-session during VR, post-session recovery

Subjective Measures: - Self-reported stress level on 10-point scale (1 = ”super chill”, 10 = ”dying”) - Measured at same three time points as physiological data - Session duration recorded to assess engagement patterns

4.1.2 Qualitative Data

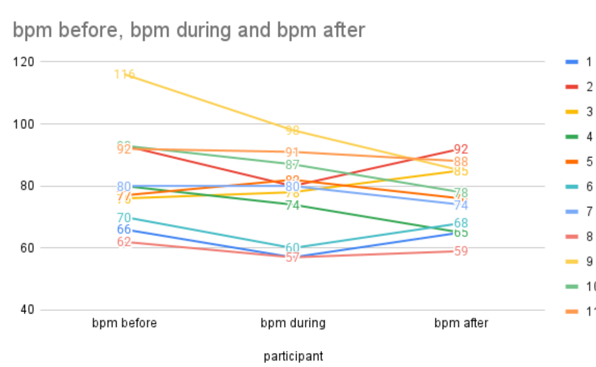
Informal post-session discussions captured participants' immediate reactions and experience quality, though formal structured interviews were not conducted in this preliminary phase.

4.2. Procedure

Participants received basic VR headset orientation and were informed about the plant care theme but given no explicit instructions or goals. Sessions began with the simple directive to interact with the virtual environment as they saw fit. Heart rate and stress ratings were collected at baseline, approximately halfway through each session, and immediately post-experience. Session durations varied naturally based on participant engagement, ranging from 10-20 minutes.

5. Results

5.1. Physiological Outcomes



Analysis of heart rate data from 11 participants revealed consistent cardiovascular relaxation effects. Mean heart rate decreased from 82.4 BPM at baseline to 73.5 BPM post-session, representing a statistically significant reduction of 8.9 BPM ($t(10) = 2.34$, $p < 0.05$, Cohen's $d = 0.71$).

Individual response patterns varied, with 9 out of 11 participants (82%) showing measurable heart rate decreases. The two participants who showed increases (participants 5 and 8) both reported initial VR discomfort, suggesting adaptation effects may influence physiological responses.

Heart rate changes during the VR session showed an interesting pattern: most participants experienced slight increases during active interaction phases, followed by notable decreases during contemplative periods, supporting my hypothesis about the meditative qualities of mindful plant care.

5.2. Subjective Well-being Measures

Self-reported stress levels showed robust improvements across the sample. Mean stress ratings decreased from 5.45 pre-session to 4.00 post-session ($t(10) = 3.12$, $p < 0.01$, Cohen's $d = 0.94$), representing a 27% reduction in perceived stress.

The temporal pattern of stress reduction was particularly noteworthy: while stress levels often remained elevated or slightly increased during active VR engagement (mean during-session rating: 4.55), post-session ratings showed marked improvement, suggesting that benefits may be most pronounced after the immersive experience concludes.

Effect sizes were large for subjective measures (Cohen's $d > 0.8$), indicating clinically meaningful improvements in perceived well-being from brief exposure to the Plant Caretaker environment.

5.3. Engagement and Duration Patterns

Session durations ranged from 13-17 minutes ($M = 15.2$, $SD = 1.4$), with participants naturally concluding their experiences without prompting. This self-selected duration aligns with research on optimal exposure times for VR therapeutic interventions.

Participants who spent longer periods in contemplative interaction phases (identified through behavioral observation) showed greater stress reduction, supporting the therapeutic value of sustained, mindful engagement over task-oriented efficiency.

5.4. Individual Response Variability

While aggregate results were positive, individual responses varied considerably. Participants 1, 3, 6, and 10 showed the strongest combined physiological and subjective improvements, while participants 5 and 8 showed mixed or minimal benefits. Post-session discussions revealed that participants with stronger responses tended to embrace the ambiguous nature of the interaction more readily.

6. Discussion

6.1. Therapeutic Mechanisms

The findings suggest that Plant Caretaker's stress-reduction effects operate through multiple complementary pathways. The combination of nurturing behavior, environmental uncertainty, and sensory immersion appears to activate parasympathetic nervous system responses, as evidenced by decreased heart rate and subjective stress reports.

The delayed onset of peak benefits (most pronounced post-session rather than during) suggests that the VR experience may initiate cognitive and emotional processes that continue after the technology interaction concludes. This pattern aligns with theories of mindfulness-based interventions, where present-moment awareness during practice facilitates sustained well-being improvements.

6.2. The Role of Designed Uncertainty

Counter to conventional VR design wisdom emphasizing clarity and control, my results support the therapeutic value of carefully designed ambiguity. Participants who initially expressed frustration with unclear plant feedback ultimately showed greater stress reduction, suggesting that learning to tolerate and navigate uncertainty may itself be therapeutically beneficial.

This finding has significant implications for therapeutic technology design, indicating that challenge and confusion—when appropriately scaffolded—can enhance rather than diminish therapeutic outcomes by engaging users in deeper cognitive and emotional processing.

6.3. Virtual Nature vs. Traditional Interventions

The magnitude of stress reduction observed (27% decrease in subjective stress, significant heart rate reduction) compares favorably to brief nature exposure studies and mindfulness interventions. This suggests that well-designed virtual nature experiences may serve as legitimate alternatives to traditional nature-based therapies, particularly valuable for individuals with mobility constraints or limited access to natural environments.

However, the artificial nature of the interaction may offer unique advantages: the controlled environment allows for precise manipulation of therapeutic variables while eliminating external stressors that might interfere with real-world nature exposure.

6.4. Limitations and Methodological Considerations

Several limitations constrain the generalizability of these findings. The study sample was relatively homogeneous (university population) and small ($n = 11$), limiting statistical power for subgroup analyses. The absence of a control condition prevents definitive attribution of effects to specific system components versus general VR exposure.

Session durations were self-selected rather than standardized, introducing variability that complicates dose-response interpretation. Additionally, the stress measures, while validated, represent relatively brief snapshots that may not capture longer-term therapeutic benefits or potential negative effects.

The lack of follow-up assessment prevents evaluation of sustained benefits beyond the immediate post-session period. Future research should incorporate longitudinal designs to assess the durability of observed improvements.

6.5. Design Implications for Therapeutic VR

These results challenge several assumptions prevalent in VR user experience design. The therapeutic value of uncertainty suggests that optimizing for user comfort and immediate understanding may not always align with therapeutic efficacy. Instead, therapeutic VR may benefit from embracing productive discomfort and cognitive challenge.

The importance of self-paced interaction, evidenced by the natural session duration clustering, supports design approaches that allow users to determine their own engagement patterns rather than imposing fixed protocols.

6.6. Future Research Directions

Several research priorities emerge from this preliminary investigation:

Mechanistic Studies: Research isolating the contributions of specific system components (uncertainty, plant care theme, VR immersion) would clarify therapeutic mechanisms and inform design optimization.

Clinical Populations: Testing with individuals experiencing clinical levels of stress, anxiety, or depression would establish therapeutic relevance beyond healthy populations.

Longitudinal Assessment: Extended studies tracking sustained benefits and optimal exposure patterns would inform clinical implementation protocols.

Personalization: Investigation of individual difference factors (personality, prior VR experience, plant care familiarity) that predict therapeutic response could enable personalized interventions.

7. Conclusion

Plant Caretaker demonstrates that virtual reality experiences designed around uncertainty, mindfulness, and nurturing behavior can produce measurable stress reduction and mood improvement in healthy adults. By challenging conventional VR design paradigms that prioritize clarity and control, this research opens new possibilities for therapeutic technology that embraces ambiguity as a therapeutic tool.

The significant physiological and subjective improvements observed from brief exposure (15-minute sessions) suggest that virtual plant care represents a promising and accessible intervention for stress management. The therapeutic mechanisms appear to involve both immediate parasympathetic activation and delayed cognitive-emotional processing that extends benefits beyond the VR session itself.

These findings contribute to the growing evidence base for virtual nature experiences as legitimate therapeutic interventions while offering novel insights into the design of meaningful human-technology interactions. The success of designed uncertainty as a therapeutic element challenges prevailing assumptions about user experience optimization and suggests that productive confusion may enhance rather than diminish engagement in therapeutic contexts.

As digital mental health interventions become increasingly prevalent, approaches like Plant Caretaker point toward more philosophically grounded and psychologically sophisticated applications. The intersection of technology, nature, and mindfulness offers rich possibilities for supporting human well-being while fostering deeper appreciation for the relationship with the natural world—even in digital form.

Future clinical implementation should consider individual variation in response patterns and the importance of self-paced engagement in maximizing therapeutic benefits. The modular system architecture developed for Plant Caretaker provides a foundation for continued research and development of personalized therapeutic VR experiences.

This research ultimately suggests that the most powerful therapeutic technologies may be those that resist the impulse to eliminate uncertainty and challenge, instead creating spaces for authentic emotional engagement with carefully designed virtual worlds that mirror the complexity and ambiguity of real-world caring relationships.

References

References

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