Persuasive System Design for VR Meditation: A Design Science Approach to Enhancing Cognitive Absorption*

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Abstract

This study explores how Persuasive System Design (PSD) principles enhance engagement and cognitive immersion in virtual reality (VR) meditation simulation. Designed to address limited interactivity and sustained engagement in mindfulness applications, it integrates PSD features into a VR meditation prototype and evaluates their impact using a Design Science Research approach. Drawing on Cognitive Absorption (CA) theory, the study examines how persuasive elements affect users' psychological engagement with and perceptions of usability and usefulness. The developed prototype features nature-inspired, culturally informed environments incorporating key PSD features. Mixed-method evaluations, including usability testing and surveys, showed a positive correlation between CA and perceived usability. Results further indicate that persuasive features were associated with higher perceived engagement and usability. The findings illustrate how persuasive and immersive design may jointly support user engagement and mental wellbeing in VR meditation.

Keywords

virtual reality, persuasive system design, cognitive absorption, user engagement, human–computer interaction, digital wellbeing, meditation

1. Introduction

Virtual reality (VR) meditation has attracted growing interest as people seek immersive approaches to manage stress and cultivate mindfulness [1]. Unlike conventional mobile applications, which rely on audio and a flat display, VR headsets surround the user with a three-dimensional scene and spatial sound. The resulting sense of presence can quiet everyday distractions, support sustained attention to the present moment, and evoke feelings of calm or even awe [2, 3]. Early studies suggest that when the environment, pacing, and guidance are carefully designed, VR based mindfulness applications can elevate people's state mindfulness and positive affect, indicating that immersion may be a mechanism to boost wellbeing [4, 5]. For a consumer application, however, the promise of immersion is not enough. Lasting impact depends on whether people return consistently and whether the experience feels intuitive, rewarding, and worth their time.

This paper examines engagement in VR meditation through two complementary perspectives. The first is cognitive absorption (CA), defined as a state of deep involvement with technology that is marked by focused immersion, temporal dissociation, a sense of control, curiosity, and enjoyment [6]. Prior work links this form of engagement to appraisals of technology. When people are absorbed, they tend to perceive a system as easier to use and more beneficial, which in turn supports adoption of the technology [6]. In the context of VR meditation, cognitive absorption is not only an appealing experiential goal, but also a plausible pathway to acceptance. If the session reliably draws users into a calm and attentive state, they are more likely to judge the application as learnable and valuable for their routine.

The second is Persuasive System Design (PSD), a framework that organizes design principles intended to encourage and sustain beneficial behaviors and behavior change without coercion [7]. In practice this means features that scaffold the main task, offer timely and supportive feedback, and create a sense of

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gentle progression. Within consumer VR meditation, persuasive features can transform a passive scene into an active companion that guides attention, reduces confusion, and affirms effort. Evidence from digital health more broadly shows that interventions which deliberately employ persuasive elements achieve better adherence [8, 9]. Translating these ideas to immersive media suggests a concrete design opportunity. Rather than relying only on a beautiful landscape and a voice track, a VR meditation app can structure the journey, acknowledge completion, and invite return in subtle, aesthetically aligned ways.

The need for such an approach is underscored by two persistent challenges. First, adherence in consumer health technologies is fragile. Many people try meditation applications briefly and then drift away [8]. Initial novelty can engender a few sessions, but without persuasive scaffolding and a smooth experience it rarely becomes a habit. Second, usability gaps frequently interrupt flow in commercially available VR mindfulness products. Users report unclear navigation, uncertain task boundaries, and occasional technical hiccups [10]. Each interruption breaks presence, pulls attention back to the device, and makes the next session less likely. These issues are not minor. For a practice that depends on calm and continuity, any friction can erase the benefits of immersion.

This study responds by integrating persuasive design features into a VR meditation prototype and evaluating how those features relate to cognitive absorption and to users' perceptions of ease of use and usefulness. The goal is not to test clinical outcomes or compare VR to other therapies. Rather, the focus is on the design qualities that make a consumer VR meditation experience engaging enough to sustain use. The work is situated in a design science tradition [11]. A concrete artifact is built, iteratively refined, and studied to generate knowledge about how persuasive elements shape immersive engagement. Cognitive absorption provides the measurement lens for the quality of the experience, while technology acceptance perceptions indicate whether deeper engagement translates into favorable judgments about the system. The contribution of this paper is twofold. Conceptually, it links persuasive design and cognitive absorption in a concrete consumer VR use case and argues that absorption is a meaningful mediator between design and acceptance. Practically, it offers an evaluated set of design moves that preserve the contemplative character of meditation while addressing the real obstacles that keep people from returning. The findings are intended for designers and researchers who build wellbeing applications and who must balance aesthetic immersion with everyday usability.

The investigation is guided by the following research questions:

- **RQ1**: How can PSD features be embedded in VR meditation environments to support cognitive absorption?
- **RQ2**: How is cognitive absorption reflected in users' perceptions of the VR meditation application's usability in relation to PSD-aligned features?

The scope is deliberately limited to consumer VR meditation rather than clinical interventions. Participants were typical adult users seeking calm and focus, not patients undergoing therapy, and the outcomes of interest are engagement, usability, and user perceptions. This boundary avoids confounds that would accompany clinical efficacy trials and keeps attention on the design levers available to consumer product teams. While the results will not make claims about treatment effects, they can inform how future wellbeing applications, including clinical systems, might weave persuasive features into immersive environments in ways that respect the meditative goal.

In sum, the paper starts from a simple premise. Immersion is a necessary but insufficient condition for sustainable VR meditation. Engagement must be cultivated through design that guides without intruding and that rewards attention with a clear sense of progress. Cognitive absorption provides the experiential target and the evaluative lens. Persuasive System Design supplies the toolkit. By bringing these together in an interactive prototype and examining their relationships to ease of use and usefulness, the study aims to clarify how VR meditation can move from an impressive demo to a practice that people gladly return to.

2. Related Work

This section reviews prior research on VR meditation, persuasive system design, and cognitive absorption, outlining the foundations for understanding engagement in immersive wellbeing applications.

2.1. Virtual Reality for Meditation and Wellbeing

The use of VR in mental wellness has gained increasing attention due to its potential to create immersive, controlled environments that support relaxation and therapeutic practices. Early clinical applications, such as Oyama et al.'s [12] virtual forest walk for cancer patients, highlighted VR's promise in enhancing emotional wellbeing. Since then, research has demonstrated VR's effectiveness in reducing anxiety and supporting psychological health [13], positioning it as a versatile tool across healthcare domains.

Meditation, long recognized for improving attention, stress resilience, and interpersonal skills [14], has increasingly been integrated into VR environments. Immersive VR can minimize external distractions, guide user attention, and strengthen the meditative state [15]. The sense of presence—defined as both the illusion of "being there" and the plausibility of events—is central to VR meditation, enabling users to focus more fully on the present moment [16, 3]. Empirical studies confirm that VR-supported mindfulness interventions can improve state mindfulness, reduce negative emotions, and enhance relaxation [4, 5].

Beyond clinical contexts, VR meditation tools have shown promise in everyday settings. For example, Li et al. [17] report that VR-based meditation reduced negative mood among healthcare workers during the COVID-19 pandemic, while Failla et al. [5] found that even single VR sessions enhanced mindfulness skills in non-clinical populations. These findings suggest that VR may overcome barriers such as limited access, motivational challenges, or environmental distractions that often hinder traditional mindfulness practice.

Nevertheless, challenges remain. VR meditation apps often struggle with sustaining engagement, with short session durations and limited repeat use [18]. Technical issues such as headset discomfort and video fidelity can also disrupt immersion [3]. Furthermore, most studies to date rely on guided meditations in nature-inspired settings, with limited exploration of interactive or body-based approaches that might deepen engagement [19].

2.2. Persuasive Systems Design in Digital Health and VR

PSD is a framework for developing and evaluating technology-based interventions aimed at influencing users' attitudes or behaviors, structured around 28 principles categorized into primary task support, dialogue support, system credibility, and social support [7]. PSD has been applied across various domains, including coronary heart disease management [20], substance use prevention [21], and physical activity promotion for individuals with chronic conditions, such as chronic obstructive pulmonary disease [22]. Research indicates that features like reduction and self-monitoring (primary task support) and reminders (dialogue support) are commonly used and effective in web-based health interventions [21], while social support features have shown mixed user reception [22]. Moreover, the extent to which PSD principles are applied has been positively associated with adherence to digital interventions, underscoring the importance of a balanced application of support categories [8]. While no ideal combination of techniques has been identified, personalization, simulation, and praise are often used to stimulate motivation [23]. The development of effective persuasive health technologies requires a human-centered design approach and consideration of user context [24].

2.3. Cognitive Absorption and Immersive Experiences

CA is a multidimensional construct describing an individual's deep involvement in sensory and imaginative experiences that can alter perception, memory, and mood [25]. CA draws from theories of absorption as a personality trait, flow, and cognitive engagement [26], and has been applied to diverse contexts, including social media engagement and health interventions. For instance, CA influences how users perceive the quality of brand-related content and drives online engagement behaviors [27]. Its relevance to both consumer technology use and mind-body interventions highlights its interdisciplinary importance [25, 27].

In persuasive and hedonic contexts, CA plays an important role in user adoption and sustained engagement. Flow, a state of deep enjoyment and absorption [28], has been shown to reinforce technology acceptance, especially in VR applications where both utilitarian factors (ease of use, perceived usefulness) and hedonic experiences drive intentions to engage [29]. CA and perceived persuasiveness influence adoption of gamified systems for sustainable behaviors [30].

CA is also integral to the effectiveness of PSD in health and wellbeing contexts. Strategies such as goal setting, feedback, and self-monitoring have been widely applied in eHealth interventions [23, 24]. In VR, these strategies are recommended to strengthen intrinsic motivation and involvement [31]. Personalized persuasive features, when aligned with users' psychological profiles, enhance engagement and behavior change, though credibility and social support elements must be carefully balanced [32].

Despite these benefits, ethical concerns remain. PSD and CA-enhancing strategies may inadvertently cross into manipulation, particularly in immersive VR where the persuasive impact is amplified. Research on "dark patterns" highlights the risk of design practices that prioritize commercial over user wellbeing [33]. Accordingly, ethical safeguards are necessary to maintain user autonomy and trust [34].

In VR meditation specifically, CA and presence contribute to heightened relaxation and awe but may also increase fatigue or distress, particularly in sensitive populations [2]. Technical and practical barriers—such as hardware limitations, fragmented development tools, and privacy concerns—further constrain adoption [35]. Nevertheless, VR meditation demonstrates potential for both clinical and home use, provided that design strategies leverage CA responsibly while addressing accessibility and ethical considerations.

3. Methodology

This research adopts a Design Science Research (DSR) approach to guide the systematic development and evaluation of a VR meditation application. DSR is a valuable methodology for developing and evaluating technological artifacts to address complex organizational problems in information systems [11]. By extending human and social capabilities through innovative artifacts, DSR can significantly impact behavior, potentially rendering previously established behavioral laws irrelevant [11]. This makes DSR a justified approach for developing technology-driven behavioral interventions. The framework aligns well with the objectives of this study, as it supports the iterative development of an artifact, in this case, the design of an interactive VR application that integrates PSD features to influence user behavior, specifically to enhance CA during meditation. This study adopts the DSR framework proposed by Peffers et al.[36], which outlines a structured, six-step process for the development and evaluation of innovative artifacts (Table 1). The artifact developed in this study serves as a designed solution to two interconnected problems identified in prior research: (1) the limited use of PSD features in VR health and mindfulness applications, and (2) the need to evaluate the effectiveness of such features in enhancing user engagement, specifically through CA.

4. Artifact Development

The artifact, XR Meditation prototype, was developed as both a meditation tool and a research instrument to examine how persuasive elements influence CA and user perceptions of usability and usefulness.

4.1. Overview of the XR Meditation Application

The XR Meditation prototype was developed in Unreal Engine 5 and optimized for deployment on the Meta Quest devices, with the long-term aim of providing a consumer-level meditation experience. The conceptual foundation was inspired by nature-based mindfulness practices and the notion that

Table 1
Summary of the six DSR phases and their implementation.

DSR Phase	Activities	Output
Problem Identification & Motivation	Literature review on VR meditation, PSD, CA; identification of engagement gap	Defined research gap and problem statement
Define Objectives of a Solution	Translation of CA and PSD into design and evaluation requirements	Clear artifact objectives and evaluation criteria
Design & Development	Iterative development of a VR prototype integrating selected PSD features	Functional VR artifact
Demonstration	Pilot and UX/usability testing across prototype iterations	Proof of artifact feasibility
Evaluation	CA measurement, PSD perception scales, statistical testing	Empirical validation of PSD–CA relationship
Communication	Theoretical synthesis and design implications	Academic contribution and practical guidance

immersive digital environments can promote calmness, focus, and psychological restoration. Rather than relying on task-oriented interaction, the design emphasizes slow-paced exploration, ambient storytelling, and minimal interface elements.

Navigation relies on hand controllers with intentionally limited movement speed to preserve the application's meditative tone. Head tracking and touch-based triggers enable embodied interaction, replacing menus and heads-up displays with contextual cues and environmental feedback. The minimalist design avoids conventional gaming affordances, prioritizing immersion, natural engagement, and a contemplative atmosphere. The application world is structured around two distinct but interconnected meditation zones: a Finnish forest and a Japanese forest. Users first enter a neutral onboarding space, where core controls and interaction mechanics are introduced. This area also enables environment selection, allowing users to begin with either the narrative-driven Finnish setting or the more open Japanese landscape.

The Finnish forest zone is characterized by Nordic natural elements—pine trees, mossy pathways, lakesides, and bridges—and introduces Kokedama (Figure 1), a floating moss spirit adapted from Japanese cultural symbolism. Kokedama functions as a virtual guide, providing subtle narration and breathing prompts that support users' initial orientation. Guided by this character, users follow a narrative path punctuated by meditation hotspots such as lakeside benches, stone circles, and forest clearings. These areas facilitate practices including gaze meditation, mindful breathing, and tree-focused attention. Ambient sounds, biophilic details such as falling leaves or butterflies, and context-sensitive audio cues reinforce immersion. At midpoints, interactive tasks such as a stone-skipping activity introduce playful engagement and sustain attention without disrupting the contemplative rhythm. Visual highlights and subtle animations, such as blooming flowers or denser grass after meditation, act as environmental feedback, encouraging reflection and reinforcing task completion.

The Japanese forest serves as a complementary environment with an emphasis on aesthetic variety and symbolic resonance (Figure 2). Cherry blossoms, Zen gardens, waterfalls, and shrines create a distinct visual and cultural tone. Unlike the Finnish forest, this environment omits a guiding character, offering instead a more autonomous meditative experience. Interaction remains consistent, relying on gestures and environmental cues, but the progression is shaped more by visual storytelling and ambient design. The contrast between guided and unguided modes allows exploration of how structured versus self-directed mediation affects CA and perceptions of persuasiveness.

4.2. Implementation of PSD Features

The implementation of PSD features in the artifact aimed to enhance engagement through immersive, non-intrusive interactions consistent with meditation. Rather than adopting all PSD principles, the design focused on Primary Task Support and Dialogue Support, which best aligned with fostering

Figure 1: Finnish forest environment showing Kokedama's first appearance (left) and a meditation spot (right).

Figure 2: The Japanese forest environment.

cognitive absorption in solitary, nature-based VR meditation. The decision to exclude Social Support and System Credibility categories was not incidental but driven by careful consideration of the experiential qualities desired in VR meditation, as explained in this section.

Primary Task Support was central to structuring the meditation flow. Reduction was achieved by designing clear, simple pathways that minimized navigational complexity, thereby lowering cognitive load. Tunneling was realized in the Finnish forest, where Kokedama gradually introduced interactions and meditation practices, effectively functioning as a tutorial embedded within the environment. Self-monitoring was supported by the linear map design, which made progress intuitive and provided a sense of accomplishment as users advanced through hotspots. Rehearsal was enabled by allowing repeated access to meditation areas, encouraging reinforcement of practices and familiarity with the environment. Together, these features guided user focus without overwhelming them, promoting CA by aligning system structure with meditative goals.

Dialogue Support, which includes elements such as praise, rewards, suggestions, liking, and social role, is thoughtfully integrated into our artifact to enhance user engagement without disrupting immersion. Praise is delivered subtly through brief, spiritual dialogue from Kokedama after the completion of meditation sessions, offering gentle encouragement to motivate continued participation. Rewards are implemented through subtle environmental changes, for example, after completing a mindful session at a tree trunk, users may notice that flowers bloom or grass becomes denser, serving as a non-intrusive form of positive feedback that avoids the distraction of overt gamification. Suggestion is provided by Kokedama, who gives clear, calm instructions upon the user's arrival at meditation spots, ensuring smooth guidance without breaking the meditative flow. The liking principle is addressed by designing visually rich and aesthetically pleasing environments inspired by real Finnish and Japanese forests, enhanced with unique elements like distant mountain views to deepen immersion. Finally, the system adopts a social role through Kokedama, who functions as a gentle virtual coach and companion, reinforcing engagement and presence within the VR experience.

Social Support, while potentially valuable in many digital health interventions, was excluded primarily due to concerns about its compatibility with immersive, individual meditation experiences. Research indicates that social features such as competition, social comparison, or peer feedback can disrupt the introspective and calming objectives of meditation, particularly in VR environments [37, 38]. Moreover, prior PSD research suggests that Social Support mechanisms interact with and reshape CA dimensions, potentially altering immersion dynamics [30]. Given that the focus of this application is to foster deep personal engagement rather than social interaction, the risk of compromising immersion outweighed the potential persuasive benefits of social support mechanisms.

System Credibility features, which include attributes such as trustworthiness, authority, and third-party endorsements, were also intentionally omitted in the initial design phase. This was primarily due to the early prototype nature of the artifact, where credibility mechanisms (e.g., certifications, affiliations, user testimonials) had not yet been formally established or validated. Including such features without empirical backing could potentially introduce artificial or unfounded claims, inadvertently affecting user trust. Furthermore, in the context of a nature-based meditative experience, credibility signals are less likely to be cognitively salient compared to in-task engagement cues. Since the immersive design seeks to minimize interface distractions and support focused presence, the inclusion of overt credibility messaging (e.g., badges, institutional logos, data transparency overlays) was considered misaligned with the experiential goals of the system.

4.3. Alignment with CA Constructs

The artifact was developed with careful consideration of CA, a multidimensional construct that includes temporal dissociation, focused immersion, heightened enjoyment, control, and curiosity [6]. Temporal dissociation is fostered through immersive natural environments enriched with ambient sounds such as footsteps, rustling leaves, flowing waterfalls, fluttering butterflies, and falling foliage, which help users lose awareness of time. Focused immersion is supported by gaze-based meditation practices and a minimalistic UI design that reduces cognitive load and promotes flow, encouraging users to concentrate on singular natural elements like a flower, treetop branches, or drifting clouds. Control is achieved by allowing users to freely explore the environment and choose their preferred meditation styles and pace, enhancing their sense of autonomy and mastery. Curiosity is stimulated through mythical and interactive elements, such as forest spirits, the guiding presence of Kokedama, Zen statues, a Japanese dam flanked by cherry blossom trees, and playful features like stone skipping, that invite exploration and discovery. Enjoyment is heightened through emotionally resonant visual and auditory experiences, including forest bathing, moments of stillness where users can sit or lie down, and immersive cultural aesthetics that foster a sense of peace and pleasure within the virtual environment.

4.4. Iterative Design and Refinement

An iterative development process was adopted to refine usability and ensure alignment with PSD principles (Figure 3). The system evolved through three cycles of development, testing, feedback, and refinement. Iteration 1 produced the initial prototype featuring a stylized Finnish forest and early PSD elements such as Reduction, Tunneling, and Dialogue Support. A pilot test (n = 5) informed improvements to controls and onboarding. Iteration 2 introduced the Japanese map, introducing biophilic diversity and enhanced interactions. Two independent datasets (n = 6 per group) were collected during Iteration 2. Group A evaluated the usability of an earlier version of the prototype, while Group B evaluated an updated build. The participants in the two groups were different. Iteration 3 validated PSD effectiveness and CA through structured testing (n = 11), revealing improved engagement, ease of use, and meditative satisfaction, confirming alignment with persuasive design objectives.

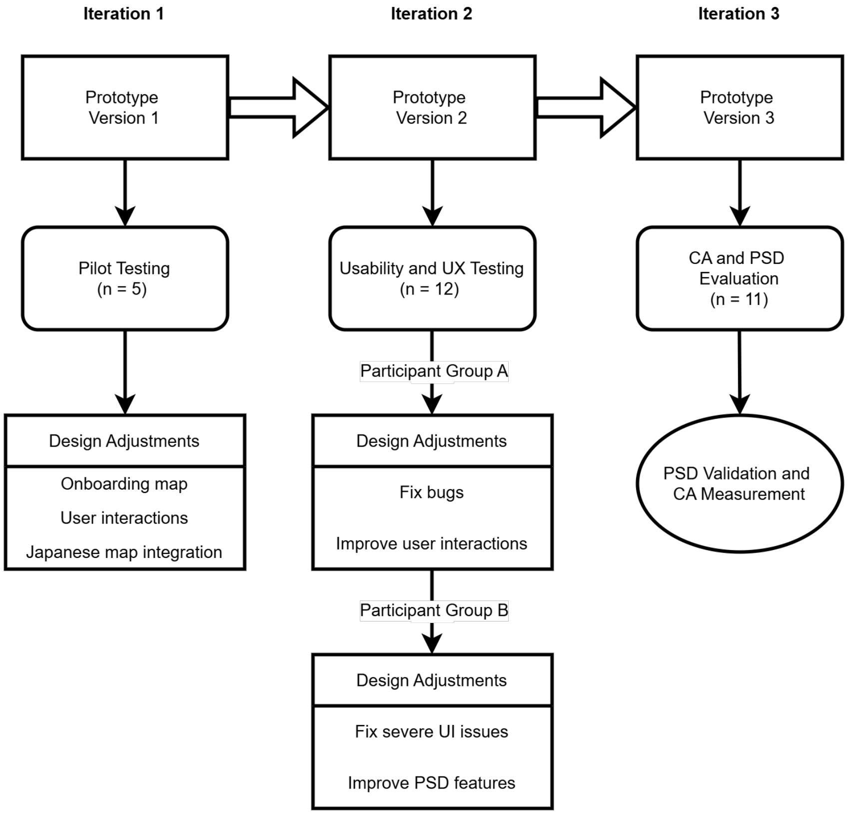

Figure 3: Overview of the iterative design and refinement process.

5. Evaluation

The evaluation unfolded across three stages: pilot testing, UX & usability evaluation, and assessment of CA and perceived persuasive design. Organizing the work in this sequence allowed us to converge on interaction and feedback problems that mattered most to users, and then quantify CA and PSD perceptions under controlled conditions. All data collection procedures adhered to ethical guidelines for research involving human participants, and informed consent was obtained prior to data collection. Participation was voluntary, data were anonymized and securely stored in compliance with GDPR and University of Oulu ethical standards, and participants could withdraw at any time without penalty.

5.1. Pilot Test

The pilot test served as an initial feasibility check for the prototype's intended experience. Conducted during a research demonstration event with five adult participants who voluntarily engaged with the prototype and completed a short post-session survey. Despite distractions, most participants reported feeling immersed, validating the prototype's environmental and auditory design. However, issues such as motion discomfort, unclear task boundaries, and uncertainty about next steps disrupted flow. These findings led to targeted refinements, including improved onboarding, clearer guidance timing, and stronger in-environment feedback cues. The pilot also confirmed the suitability of the data collection methods, laying the foundation for subsequent structured evaluations.

5.2. UX & Usability Testing

A comprehensive usability and UX evaluation was conducted during Iteration 2 of the development phase, following the pilot, to assess interaction quality, navigation flow, and user engagement. Participants were adults recruited via university-based convenience sampling from a master's-level UX course; student groups self-selected the prototype for usability evaluation and had varying levels of experience in VR and meditation. Testing took place in a controlled setting using Meta Quest headsets, with sessions lasting 30–40 minutes and incorporating surveys, observations, and semi-structured interviews. Researchers remained present for technical support but minimized interaction during immersion to reduce observer influence. Observational and interview data were systematically reviewed, coded for recurring issues, and grouped into thematic categories to identify consistent usability patterns. Refinements were introduced iteratively, including clearer onboarding, participant-controlled session starts, and reduced observer presence to improve comfort and immersion. Findings from this phase informed key interface and usability improvements ahead of the final evaluation phase.

5.3. CA & PSD Evaluation

The final evaluation phase examined the relationship between CA and PSD features in the refined prototype to validate persuasive mechanisms and their influence on immersive engagement. Participants (n = 11) were adults (25–35 years), bachelor's–master's level university students recruited voluntarily through the authors' network using convenience sampling, with experience ranging from none to moderate in VR and meditation. Participants completed two sessions: a guided meditation session in the Finnish forest incorporating key PSD elements and an unguided session in the Japanese forest. The guided session used voice narration to support mindful breathing and environmental awareness, while the unguided session allowed free exploration for relaxation. Participants first completed the Finnish forest session, followed by post-session surveys assessing perceived PSD features, CA, and perceived usability (ease of use and usefulness). They then completed Japanese forest session and a subsequent survey assessing CA and perceived usability. Session order was not randomized to provide structured onboarding. Because the same participants took part in both sessions, two distinct environments were used to reduce familiarity and carryover effects that could arise if CA were measured with and without PSD features in the same scenario. Sessions were conducted in a distraction-free laboratory using a high-performance PC–tethered Meta Quest headset, with data collected via surveys, in-VR recordings, and behavioral observations. One researcher remained present for session guidance and technical oversight but did not intervene unless assistance was requested. Given the limited sample size, this evaluation is exploratory in nature and relies on non-parametric statistical analyses.

6. Results

Findings presented here build on the dataset originally reported in the referenced master's thesis [39].

6.1. UX/Usability Findings

This section combines quantitative metrics with qualitative observations to assess how effectively the prototype supported intuitive, comfortable, and engaging interaction. Two participant groups interacted with different versions of the prototype, with Group B using a refined build based on Group A's usability evaluation. Task success patterns indicate improvements from Group A to Group B across comparable tasks (Table 2).

Qualitative observations show that, for Group A, the most disruptive issues were the absence of visible in-game hands and unclear interaction cues. The Kokedama guide occasionally advanced before participants had completed a task, thereby eroding trust in the intended tunnelled flow. In Group B, participants reported occasional disorientation due to camera speed, inconsistent view transitions, audio issues, and intermittent visibility of interactive elements. These issues were more cosmetic compared to the fundamental affordance gaps observed in Group A. Across both groups, participants consistently praised the aesthetic fidelity and calming atmosphere of the environments and credited narration with easing them into the guided sequence when timing aligned. Overall, findings from Group A highlighted critical areas requiring refinement, while targeted improvements enhanced usability and established a stable foundation for the final evaluation phase.

Table 2
Task success rates for participants in the Finnish forest environment (n = 6 per group).

Group	Task	Success Count	Success Rate
Group A	Meditate on a tree trunk	2/6	33%
	Skip stones at the lake	3/6	50%
Group B	Meditate on a tree trunk	5/6	83.3%
	Skip stones at the lake	6/6	100%

6.2. PSD Perceptions

To evaluate how users perceived the persuasive elements embedded in the XR Meditation prototype, participants (n = 11) completed a post-test questionnaire following the Finnish-forest session, where Primary Task Support and Dialogue Support were most prominently implemented. Survey items were derived from the PSD model [7], with item wording adapted from Beerlage-de Jong et al. [40] to fit the VR context and a 7-point Likert scale. Adaptations were limited to wording and response scaling, while construct definitions were preserved. Construct-level means and standard deviations (SD) were calculated to capture perceived strength and consistency of PSD-related features (Table 3).

Overall, participants reported high recognition of PSD-based features, particularly those promoting guidance and engagement. Dialogue Support achieved the highest mean, indicating that users consistently noticed and valued the gentle feedback and voice-based cues provided by Kokedama. Primary Task Support also scored strongly, confirming that the system's structured path and intuitive progression effectively supported user focus. Perceived Persuasiveness and Continuance Intentions were likewise positive, suggesting that users found the experience motivating and worth repeating.

Variability in Unobtrusiveness, Effort, and Effectiveness indicates individual differences in comfort, cognitive load, and perceived benefit—factors likely shaped by prior VR experience and meditation familiarity. Due to the small sample size, internal-consistency checks were conducted for exploratory purposes only. Preliminary reliability analysis (Cronbach's $\alpha > 0.80$ for PERS, UNOB, and CONT) supports acceptable internal consistency for these constructs, although the limited sample constrains confirmatory interpretation. Conversely, low α values for PTS and DS suggest a need to refine item phrasing to better capture how users conceptualize guidance and feedback within immersive contexts.

Taken together, PSD features in the guided (Finnish) scenario were salient and well-received, especially the narrative guidance and task structuring that anchored attention and supported progression. Variability in Unobtrusiveness, Effectiveness, and Continuance underscores the need for adaptive, less intrusive cueing and reduced cognitive overhead at key interaction moments. With targeted refinements to cue timing, feedback consistency, and personalization, the persuasive layer can better align with meditative flow while sustaining users' motivation to return.

6.3. CA Comparisons

CA was assessed using five dimensions—Temporal Dissociation, Focused Immersion, Heightened Enjoyment, Control, and Curiosity—derived from Agarwal and Karahanna's [6] validated model. Item wording was adapted for the VR meditation context, while the underlying construct definitions were preserved. Each construct was rated on 7-point Likert scales, with higher scores indicating stronger absorption. Out of eleven participants, ten completed both meditation sessions (guided Finnish forest and unguided Japanese forest); one participant withdrew after the first session.

Table 3
Summary of perceived PSD constructs and interpretation.

Construct	Mean	SD	Interpretation
Primary Task Support (PTS)	5.52	0.54	Strong presence perceived
Dialogue Support(DS)	6.15	0.66	Strong presence perceived
Perceived Persuasiveness (PERS)	5.36	0.94	Strong persuasive impact
Perceived Unobtrusiveness (UNOB)	4.98	1.53	Moderate fit, mixed perceptions
Perceived Effort (EFFO)	4.91	1.10	Moderate cognitive load
Perceived Effectiveness (EFFE)	4.91	1.33	Users vary in perceived benefit
Use Continuance (CONT)	5.14	1.37	High likelihood of future use

A Wilcoxon Signed-Rank Test, performed using the Jamovi statistical software suite, compared overall CA scores between the two environments (Table 4). Results indicated no statistically significant difference, W = 36.0, p = .432, though the guided Finnish Forest scenario (M = 5.55, SD = 0.415) produced slightly higher and more consistent CA scores than the unguided Japanese Forest (M = 5.33, SD = 0.724) (Table 5). The effect size (r = 0.309) suggests a small-to-moderate practical difference that may reflect enhanced focus and emotional engagement when persuasive guidance is present.

Table 4
Wilcoxon signed-rank test results for CA across Finnish (CA_{A}) and Japanese (CA_{B}) environment.

Comparison	Statistic	p	Mean Diff.	SE Diff.	Effect Size
CA_{A} vs. CA_{B}	Wilcoxon $W = 36.0$	0.432	0.135	0.202	Rank-biserial $r_{\mathrm{rb}} = 0.309$

Note. $H_a: \mu_{\mathrm{A}} - \mu_{\mathrm{B}} \neq 0$.

Table 5
Descriptive statistics for CA in both scenarios.

Scenario	N	Mean	Median	SD	SE
CA_{A}	10	5.55	5.50	0.415	0.131
CA_{B}	10	5.33	5.42	0.724	0.229

Spearman's rho correlation analysis was conducted to examine the relationships between CA, Perceived Ease of Use (PEOU), and Perceived Usefulness (PU). This non-parametric test was selected due to the small sample size and the ordinal nature of the survey data, which was collected using 7-point Likert scales. Results revealed a statistically significant moderate positive association between CA and PEOU, $\rho(18) = .509$, p = .022, indicating that users who felt more cognitively immersed also perceived the system as easier to use. The relationship between CA and PU was positive but not significant, $\rho(18) = .403$, p = .078. A strong correlation was observed between Ease of Use and Usefulness ($\rho = .656$, p = .002), reaffirming their interdependence within technology-acceptance constructs. These results suggest that immersive engagement supports intuitive interaction and may indirectly influence perceptions of practical value.

7. Discussion

7.1. Interpretation of Results

Synthesizing results across all evaluation phases reveals a coherent picture of the XR Meditation prototype's performance and user experience. The pilot test identified initial barriers to immersion and comfort, which were effectively mitigated through iterative refinements validated in later usability testing. Quantitative measures confirmed clear usability gains between early and revised versions, while qualitative feedback consistently emphasized the importance of feedback clarity, audio consistency, and intuitive interaction cues.

The CA and PSD analyses further triangulated these observations. Users reported strong perceptions of Primary Task Support and Dialogue Support, which aligns with feedback highlighting the importance of environmental aesthetics and guided narration. These features were experienced as supportive and calming. However, constructs like Unobtrusiveness and Perceived Effort showed higher variability, suggesting that while the prototype is persuasive for some, it remains demanding or intrusive for others. This split was further illustrated in CA scoring: the Finnish Forest environment had slightly higher and more consistent CA scores, while the Japanese Forest showed wider variance.

Despite the lack of statistical significance, the effect size from the CA comparison ($r = .309$) indicates a meaningful difference for certain users, especially those who benefited from structured guidance. The correlation analysis reinforced these findings, showing that greater cognitive absorption was significantly linked with perceived ease of use ($p = .022$), and moderately associated with perceived usefulness. These findings affirm past research by Agarwal and Karahanna [6], which emphasized the role of absorption in technology adoption.

Taken together, the synthesis of quantitative metrics and qualitative observations provides several key insights. Immersive design elements, such as naturalistic environments and guided narration, appear to support calming and engaging user experiences. Although iterative refinements improved usability for many participants, unfamiliarity with VR remained a contributing factor to usability challenges, particularly motion-related discomfort. Cognitive absorption in the guided environment (Finnish Forest), which incorporated specific PSD features, was slightly higher than in the unguided condition, suggesting potential benefits for perceived usability. However, further studies are needed to more clearly understand this relationship.

7.2. Comparison with Existing Literature

The results of this study are broadly consistent with prior research on VR meditation, persuasive system design, and technology adoption, while also contributing new insights into how these domains intersect. Previous studies have established that VR meditation can foster state mindfulness, reduce negative emotions, and support relaxation by enhancing presence and minimizing external distractions [4, 3]. The current findings extend this understanding by empirically demonstrating how specific design features particularly those informed by the PSD model can further deepen users' immersive engagement. This study also confirms the theoretical model proposed by Agarwal and Karahanna [6], which posits that CA is a key antecedent of perceived ease of use and usefulness. The observed positive correlation between CA and perceived ease of use supports this relationship in the VR context, reinforcing the idea that immersive psychological engagement can improve users' technological evaluations. This study adds to this body of knowledge by exploring CA's relevance in a wellness-focused, consumer-level VR application, which remains an underexplored domain.

7.3. Design and Practical Implications

The findings from this study offer several actionable insights for designers and developers of VR meditation applications seeking to enhance user engagement, satisfaction, and long-term adoption. From an immersion standpoint, high-fidelity natural environments supported by ambient audio can enhance focus and temporal dissociation, key elements of cognitive absorption, while environmental storytelling and multisensory feedback enrich immersion. However, sensory intensity should be balanced with comfort, as some participants experienced motion sickness or disorientation due to navigation or hardware issues. Providing customizable movement options, such as teleportation or adjustable speeds, can accommodate diverse user needs. A minimalist interface and restrained use of gamification help maintain the contemplative atmosphere, while clear visual cues and low-friction interactions promote autonomy and flow. Collectively, these strategies foster a calming, intuitive, and user-centered design that supports sustained engagement and wellbeing in VR meditation applications.

8. Limitations & Future Research

8.1. Limitations

While this study provides valuable insights into the application of PSD and CA in VR meditation, several limitations should be acknowledged. Although the overall sample size was 28, the sample size for the CA and PSD evaluation phase was relatively small (n = 11), which limits statistical power and generalizability. Non-parametric methods mitigated this constraint, but findings, especially correlations and group comparisons, should be interpreted cautiously. Participants were recruited through convenience sampling within university networks, which may introduce sampling bias and limit the generalizability of findings beyond a relatively homogeneous, technology-familiar population. Methodologically, the study relied on self-reported data from Likert-scale surveys and interviews; although based on validated frameworks, some constructs showed low internal consistency, indicating a need for revalidation in immersive contexts. The absence of physiological measures such as heart rate variability or EEG also limited the objectivity of engagement assessment. Technological factors further affected results, as performance differences between the Meta Quest devices and high-end PC setups, along with usability issues may have influenced user engagement and CA outcomes.

8.2. Future Research Directions

Building on this study's insights and limitations, future research should further examine PSD and CA in VR meditation through more diverse and data-driven approaches. Integrating physiological and behavioral measures such as heart rate variability, galvanic skin response, and EEG could objectively assess engagement, stress reduction, and attention, complementing self-reported CA scores. Expanding demographic diversity across age, culture, and familiarity with VR or meditation would improve generalizability and reveal how user traits shape absorption and adoption. Comparing standalone and PC-tethered systems could clarify how hardware performance affects immersion and usability, guiding design choices for different contexts. Longitudinal studies are also needed to evaluate how engagement and habit formation evolve over time, addressing whether persuasive features sustain long-term use or lose impact with repetition. Collectively, these directions would advance understanding of how to design ethically persuasive, accessible, and psychologically effective VR meditation tools that support lasting wellbeing.

9. Conclusion

This study explored how PSD principles can be embedded in VR meditation environments to support cognitive absorption and how immersive engagement is reflected in users' usability perceptions. The findings indicate that PSD-aligned features, particularly those supporting guidance and feedback, are associated with stronger cognitive absorption and more favorable evaluations of ease of use. Practically, effective VR meditation design should balance sensory richness with clarity and comfort, using subtle guidance, responsive feedback, and minimal interfaces to sustain engagement without disrupting meditation. At a broader level, this research underscores that persuasive and usability-oriented design are not separate pursuits but complementary dimensions of immersive experience design. By combining behaviorally informed design principles with attention to cognitive and emotional engagement, VR meditation applications can move beyond novelty to provide meaningful, sustainable wellbeing benefits.

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Declaration on Generative AI

During the preparation of this work, the authors used the GPT-4o model developed by OpenAI solely for grammar checking, clarity improvement, and occasional translation support. All research activities, including the literature review, prototype development, evaluation, and data analysis, were conducted independently by the authors. The authors reviewed and edited the content after use and take full responsibility for the accuracy, integrity, and originality of the work. Generative AI tools were not credited as authors and bear no responsibility for the academic or scientific contributions of this paper.

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