An Immersive Multisensory Module for Relaxation and Self-Improvement: The IMMERSI Project

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***Abstract*— This paper presents the technological, methodological, and conceptual framework of Immersive Multisensory Module and Experience for Relaxation and Self-Improvement (IMMERSI), an integrated research and development initiative aimed at creating advanced Multisensory Environments (MSEs) for therapeutic, assistive, and educational applications. A defining and central element of the project is the design and development of an innovative, customizable, and highly modular immersive device, conceived as a fully accessible Immersive-Proprioceptive Seating System. This device is engineered to integrate seamlessly into immersive multisensory rooms and to function as both an interaction hub and a non-invasive sensing platform. Through embedded physiological, behavioral, and proprioceptive sensors, the seating system continuously captures user parameters and responses to multisensory stimuli. These data streams support Artificial Intelligence-based personalization pipelines capable of adapting sensory scenarios in real time according to the user's psycho-physical state. The IMMERSI framework combines multimodal sensing, artificial intelligence, immersive technologies, and orchestrated actuation to deliver adaptive, evidence-based interventions. This paper provides a comprehensive overview of the system architecture, sensing infrastructure, Artificial Intelligence (AI) cognitive layers, multisensory interaction modules, integration logic, methodological workflow, and validation paradigms designed for the development of next-generation intelligent MSEs.**

Keywords-multisensory environments; Immersive-Proprioceptive Seating; multimodal sensing; artificial intelligence; actuated environments; wearable sensors.

I. Introduction

IMMERSI is an advanced research and development initiative focused on creating a new generation of intelligent, multisensory environments intended for therapeutic, educational, and wellbeing-related applications. The project is built with the following central idea: environments should not simply surround a user with stimuli, but actively sense, interpret, and respond to that user in real time. A primary goal of the project is an innovative immersive-proprioceptive seating device, designed around three foundational principles: 1) modularity: the device can be integrated into a wide range of immersive rooms and therapeutic settings; 2) accessibility & universal design: the seating system is engineered to be usable by individuals with different physical, cognitive, and sensory needs; 3) non-invasive continuous monitoring: embedded sensors collect physiological and behavioral data without discomfort or restrictive procedures.

This device extends the traditional concept of MSEs: instead of merely surrounding the user with stimuli, IMMERSI establishes a bidirectional interaction loop in which the environment senses and reacts. Rather than offering static, pre-configured sensory experiences, the system acts as an autonomous agent, capable of modulating lighting, sound, projection, haptics, and other sensory elements based on dynamically interpreted data.

The overall objective is to support clinicians, educators, and therapists by providing an environment that not only delivers rich sensory experiences but also measures their effects and adjusts the experience accordingly. This approach is particularly relevant in contexts such as autism, cognitive impairment, sensory modulation, and stress management, where personalized and responsive environments can meaningfully enhance outcomes.

The remainder of this paper is organized as follows: Section 2 provides an overview of the background and related work in the field of multisensory environments. Section 3 details the system architecture, including the sensing, AI processing, and actuation layers. Section 4 describes the integration methodology and validation framework. Finally, Section 5 discusses the impact, innovation, and conclusions of the IMMERSI project.

II. Background

Multisensory rooms (often referred to as Snoezelen environments) are controlled spaces designed to modulate visual, auditory, tactile, and olfactory stimuli for therapeutic, educational, and well-being purposes.

Originating from the Snoezelen movement in the Netherlands in the late 1970s, these environments evolved from non-directive relaxation spaces into technologically enriched and highly interactive systems [1][2].

From a theoretical point of view, current research defines multisensory rooms as applied environments based on the multi-sensory integration, understood in neuroscience as the set of processes in which the brain combines stimuli from different perceptual modalities to optimize perception, attention, and emotional regulation [3]. This framework has shifted the design rationale from merely aggregating sensory inputs to creating coherent, user-responsive systems.

Empirical evidence, although methodologically heterogeneous, highlights benefits across clinical and educational settings. In neurodivergent populations, particularly within autism spectrum conditions, MSEs have been shown to support self-regulation, reduce anxiety, and enhance engagement [4][5]. In gerontology and dementia care, observational and intervention studies report reductions in agitation and improvements in well-being [6]. Similar positive outcomes are noted in neurological rehabilitation and palliative care, where such environments promote comfort and participation.

Technological innovations include centralized environmental control systems, vibroacoustic tactile surfaces, immersive projection technologies, and integration with biofeedback and motion tracking, enabling real-time adaptive interaction. These developments have opened new research trajectories within Human–Computer Interaction (HCI), emphasizing co-design and personalization.

Despite increased adoption, literature underscores the need for more rigorous controlled trials, standardized protocols, and objective metrics (both physiological and behavioral) to assess the effectiveness of multisensory interventions for specific populations and conditions.

III. SYSTEM ARCHITECTURE OVERVIEW

The IMMERSI platform is planned around a hierarchical, multi-layered framework designed for modularity and functional cohesion. This structure begins with the Sensing Layer, which comprises multimodal sensing subsystems dedicated to the continuous and unobtrusive monitoring of user physiological and behavioral signals. The raw data acquired by this layer is subsequently processed by the AI Processing Layer, which serves as the central reasoning engine. Here, AI-driven modules perform multimodal data fusion and advanced classification to interpret the user's state and context. Informed by this analysis, the Actuation Layer orchestrates the user's experience through a suite of immersive and multisensory actuation mechanisms. These include modulated light, spatialized sound, projected visuals, and tactile interfaces, which collectively facilitate a responsive and engaging environment. A graphical representation of the architecture using logical blocks is shown in Figure 1.

The synchronization of these components is managed by the Orchestration & Control Layer. This core logic unit governs real-time, closed-loop feedback cycles, directs the execution of predefined scenarios, and enables the adaptive modulation of system parameters to maintain therapeutic or experimental fidelity. Underpinning the entire architecture is the Data Management Layer, which ensures robust, secure, and synchronized handling of all information. It provides functionalities for secure storage, anonymized data logging, and supports clinical data structures for research and analysis. Collectively, this layered architecture is engineered to support modular expansion and ensure interoperability with third-party devices and systems. Its inherent flexibility permits versatile deployment across a range of environments, including clinical settings, educational institutions, and rehabilitation centers.

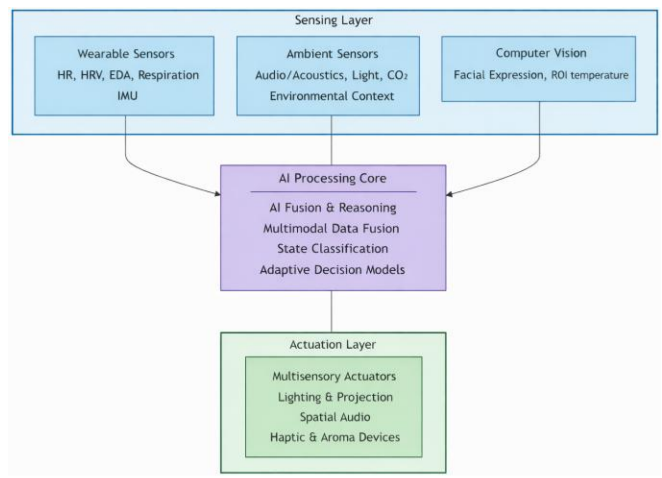

Figure 1. Representation through logical blocks of the IMMERSI system architecture.

A. Multimodal Sensing and Data Acquisition

The system incorporates physiological monitoring via a suite of devices that are structurally integrated into the Immersive-Proprioceptive Seating System (Figure 2), configured to capture a range of autonomic nervous system indicators, including cardiac activity—quantified through Heart Rate (HR) and Heart Rate Variability (HRV)—Electrodermal Activity (EDA) for the assessment of sympathetic arousal, peripheral skin temperature, respiratory patterns.

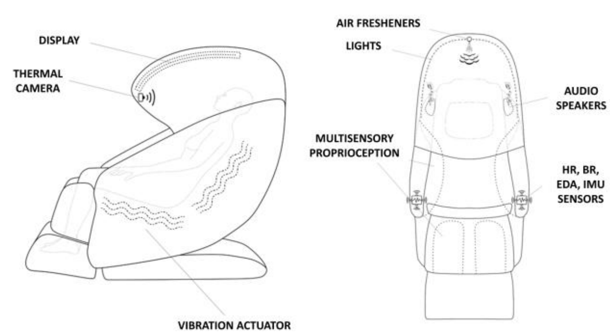

Figure 2. "Concept" of Immersive-Proprioceptive Seating System. Side view (on the left) and front view (on the right).

By being physically and functionally incorporated into the seating interface, the sensors operate in synergy with the system's proprioceptive components—such as pressure-mapping surfaces, dynamic support elements, and micro-instability mechanisms—creating a unified biosensing environment. Together, these modules generate continuous and objective streams of biometric data, which serve as critical inputs for the computational inference of affective and cognitive states including stress, engagement, arousal, and relaxation.

This holistic integration allows the Immersive-Proprioceptive Seating System not only to sense the user's physiological activity but also to contextualize it within their proprioceptive behavior, enabling richer multimodal modeling and more precise adaptive feedback.

The environment is equipped with a multimodal detection system providing contextual information. It includes microphone arrays for acoustic scene analysis and sound event classification, and ambient monitoring sensors to record parameters (e.g., illuminance, ambient temperature, CO_2 levels), enabling a more context-sensitive interpretation of user state. In addition, a series of vision-based analysis modules are implemented to classify facial expressions and measure the temperature of specific Regions of Interest (ROIs) on the face. These modules contribute to the automatic recognition of stress levels and the identification of potentially high-risk actions. A fundamental principle of these vision modules is the protection of user privacy, using thermal cameras as acquisition device, and operating procedures for anonymized data representations and discarding or never storing raw video data.

B. *AI-Driven Decision and Personalization Engine*

The core of the platform is a Cognitive AI Layer, which is responsible for reasoning over the integrated multimodal inputs. This layer comprises several integrated components, beginning with multimodal data fusion to synthesize the continuous streams of physiological data. Subsequently, dedicated AI models perform the critical task of classifying user states, such as stress, engagement, discomfort, and relaxation. Building upon this classification, a reinforcement learning, and adaptive logic subsystem dynamically selects the optimal stimuli configurations based on real-time user feedback. Furthermore, the layer employs predictive analytics to anticipate potential user reactions and proactively propose intervention adjustments. This sophisticated AI architecture maintains continuous bidirectional communication with the actuation systems, thereby ensuring a closed-loop, dynamically adaptive user experience.

C. *Multisensory Interaction and Actuated Environment*

The system incorporates an array of immersive output modalities, including dynamic lighting systems with RGB and programmable spectral control, spatial and directional audio sources, and both interactive and passively projected visual content. This multisensory actuation is further enhanced by haptic and tactile interfaces, aroma diffusion modules, and a suite of smart objects and interactive surfaces. A central orchestration engine precisely coordinates and synchronizes these diverse modalities, ensuring that specific sensory configurations are aligned with targeted therapeutic or educational objectives to create a cohesive and goal-directed experience.

IV. System Integration, Methodology, and Validation Framework

The IMMERSI project is built around a tightly integrated technological and methodological framework designed to transform immersive environments into intelligent, adaptive, and clinically meaningful systems. The core of this framework lies in the combination of robust system integration, a structured development methodology, and a comprehensive validation strategy that ensures both technical reliability and therapeutic relevance.

At the system level, IMMERSI adopts a modular, service-oriented architecture allowing sensing, AI processing, and multisensory actuation to operate as coordinated components. A central orchestration module manages communication between devices, synchronizes sensing streams, and ensures consistent timing across lighting, audio, projection, and haptic outputs. This scheduler plays a key role in maintaining system stability, ensuring that real-time adaptation occurs without latency, interruptions, or desynchronization. Being designed as a set of interoperable modules, the architecture can be expanded with new sensors, alternative AI models, or additional actuators without compromising the system's integrity. This modularity also supports scalability, making it possible to deploy IMMERSI in diverse environments, such as clinical rooms, rehabilitation centers, schools, or research laboratories.

From a methodological standpoint, IMMERSI adopts a structured, multi-phase development process. The project begins with a systematic requirements analysis involving clinicians, educators, therapists, and technical stakeholders to identify functional needs, therapeutic goals, and constraints. Based on these requirements, architectural design is defined, with careful attention to data flow, privacy-preserving mechanisms, interoperability, and reliability. Prototype modules—including wearable sensing, computer vision, ambient monitoring, AI classification components, and multisensory control—are developed and tested independently before undergoing integration into the orchestration framework.

Once the core system is assembled, the project focuses on the creation of adaptive multisensory scenarios tailored to different user groups and therapeutic objectives. These scenarios are designed to exploit the full capabilities of the platform, engaging multiple sensory channels, and dynamically adjusting stimuli in response to user state. The development process includes iterative refinement cycles in which sensor performance, AI outcomes, and user interactions are evaluated and optimized.

A crucial component of the project is its validation framework, which assesses the system across technical, experiential, and therapeutic dimensions. The validation strategy targets a range of application domains including autism spectrum conditions, dementia, stress reduction, and rehabilitation tasks, allowing the platform to be tested in both controlled and naturalistic settings. The framework defines multiple categories of metrics intended to capture a comprehensive view of system performance and user-related outcomes. Physiological indicators, such as HRV and EDA provide objective markers of stress, arousal, and emotional engagement.

Subjective measures are also included through standardized usability assessments (e.g., System Usability Scale), perceived cognitive load, and qualitative feedback from clinicians and users. Finally, clinical outcome measures and standardized behavioral scales provide evidence of therapeutic effectiveness.

By combining these elements, IMMERSI establishes a holistic evaluation methodology that ensures the platform is not only technically robust but also clinically meaningful and user centered. The integration of sensing, reasoning, and action, combined with a rigorous design and validation process, allows IMMERSI to function as a reliable, adaptive, and scalable intelligent environment capable of supporting personalized interventions across diverse user populations.

V. Impact, Innovation, and Overall Conclusions

The IMMERSI project delivers a significant advancement in the evolution of multisensory therapeutic environments, introducing intelligence, adaptivity, and enhanced measurability compared to traditional sensory rooms typically offer. By integrating multimodal sensing, AI-driven interpretation, and coordinated multisensory actuation, the platform redefines how immersive spaces can support therapeutic, educational, and wellbeing-oriented activities.

One of the most impactful contributions of IMMERSI lies in its potential to transform subjective, operator-driven experiences into structured, data-informed interventions. The system is designed to provide rich sensory experiences while capturing user responses at physiological, behavioral, and emotional levels. This shift toward quantifiable metrics enhances the clinical utility of multisensory environments, opening the door to objective progress monitoring, personalized adaptation, and evidence-based decision support. The platform's capacity to dynamically regulate stimuli based on real-time user state ensures that experiences remain aligned with therapeutic goals, reducing the risk of overstimulation and increasing overall efficacy.

In terms of innovation, IMMERSI offers a modular architecture that supports interoperability, scalability, and extensibility. New sensors, additional actuators, or updated AI models can be incorporated without disrupting system stability, making the platform adaptable to evolving research needs and technological advancements. Its cross-domain applicability, ranging from autism intervention to dementia care, stress reduction, rehabilitation, and educational engagement, further amplifies its potential impact. The system effectively positions itself as a versatile intelligent environment framework capable of serving diverse populations and settings.

From a broader perspective, IMMERSI contributes to a paradigm shift in how immersive therapeutic spaces are conceptualized and deployed. The project illustrates that environmental intelligence, when built on rigorous sensing, adaptive reasoning, and controlled multisensory interaction, can meaningfully enhance user wellbeing while improving repeatability, transparency, and clinical rigor. The project establishes a foundation for future developments in adaptive environments, including richer behavioral analytics, advanced predictive models, and integrations with clinical decision support systems.

In conclusion, IMMERSI showcases how a strategically integrated combination of technologies can elevate immersive environments from passive sensory spaces to active, responsive, and evidence-based therapeutic ecosystems. Its methodological coherence, technical robustness, and emphasis on real-world validation position the platform as a scalable and sustainable approach for next-generation therapeutic and educational environments. The project highlights the prospective impact of adaptive multisensory systems and sets the stage for continued innovation in the field of intelligent human-centered environments.

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