Emotive Immersion: EEG-Driven AI Art in Immersive Visual Spaces (Full Dome)

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| abstract

This paper proposes a rethinking of the "Future Screen" through the integration of affective computing, generative AI, and immersive spatial display. As an advanced screen paradigm, the full dome environment transcends flat, passive interfaces and enables dynamic, multisensory, and emotionally adaptive media experiences (Von Chamier-Waite, 2013). Building on this potential, the research presents Coids, an interactive dome installation. In this work, real-time emotional states are captured using EEG-based emotion recognition. These inputs dynamically shape AI-generated visuals within a shared immersive setting. Drawing on theories of immersion, presence, AI generated visuals and affect, the study explores how physiological data, even from low-resolution consumer-grade EEG devices, can meaningfully influence audiovisual space. Audience engagement with Coids suggests that affective responsiveness enhances both immersion and a sense of personal agency. These findings point to a model of screen-based media that is adaptive, generative, embodied, and socially situated. The study contributes to a broader reconceptualization of the Future Screen. Rather than considering it a singular display technology, it can be understood as a relational system in which human emotion, machine perception and generative computation work together to shape the viewing experience.

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1. Background

Screen technologies have evolved significantly over the past century, transitioning from passive viewing surfaces to highly interactive and immersive media environments. Early display technologies, such as cathode-ray tube (CRT) screens, primarily facilitated basic visual communication with minimal interactivity. Subsequent innovations, such as liquid-crystal displays (LCDs), introduced notable improvements in portability, power efficiency, and visual clarity, ultimately replacing CRT as the dominant display technology (Kawamoto, 2002). Similarly, plasma display panels (PDP), developed initially in the 1960s, provided superior brightness, contrast ratios, and response times compared to earlier display technologies, enhancing visual experiences across various applications (Weber, 2006). These technological milestones have established a foundation for screens evolving toward richer visual and interactive experiences.

Parallel to technological advancements, the conceptual understanding of screens has expanded beyond purely technological dimensions. Screens must be understood within broader social and environmental contexts, influencing user interactions, emotional responses, and cognitive engagement with displayed content (Jones, 2013). This socio-technical perspective emphasizes that displays not only provide visual information but significantly shape user interaction patterns and audience experiences in various social and spatial settings.

Immersive display technologies, such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR), represent significant developments toward highly interactive environments that foster deeper engagement. Milgram and Kishino's (1994) "Virtuality Continuum" positions immersive environments along a spectrum ranging from purely real to entirely virtual. Within this continuum, full dome environments occupy a distinct space as augmented virtuality systems, blending projected digital content with shared physical presence (Von Chamier-Waite, 2013; Phillips, 2024). Full dome technology uniquely facilitates collective immersive experiences compared to individual-oriented head-mounted VR devices (Lantz, 2006).

However, traditional full dome environments primarily rely on static, pre-scripted content, limiting their ability to dynamically respond to audience emotional and cognitive states (Phillips, 2024). To achieve more effective interactivity, Slater and Wilbur (1997) suggest distinguishing between immersion – the technological capacity to deliver sensory realism – and presence, the psychological experience of feeling situated within a virtual environment. Enhancing presence thus requires systems capable of dynamically adapting to users' real-time emotional and cognitive states. Electroencephalography (EEG), which captures real-time brainwave patterns, offers a viable method for achieving this dynamic adaptation by allowing immersive environments to directly respond to physiological feedback (Kovacevic et al., 2015). For instance, the project *My Virtual Dream* successfully employed EEG to facilitate real-time interactions within an immersive installation, responding dynamically to users' cognitive and emotional states (Kovacevic et al., 2015). Furthermore, recent advancements indicate that integrating AI with physiological data analysis can further enhance real-time responsiveness by accurately interpreting emotional states and adjusting digital content accordingly (Du et al., 2024).

2. Immersive Environments as the Future of Screen Technology

Screen technology has evolved from passive, two-dimensional displays to interactive and immersive environments that engage multiple senses. Traditional screens, including LCD and PDP, primarily provide visual output with limited user interaction (Kawamoto, 2002). In contrast, immersive technologies, such as VR, AR, and MR, incorporate multisensory input, spatial tracking, and stereoscopic visuals, allowing for more integrated and responsive interactions (Suh & Prophet, 2018). The shift toward immersive environments is driven by advancements in display resolution, interaction design, and real-time processing, distinguishing these technologies from conventional screen-based media.

A key aspect of immersive environments is the distinction between immersion and presence. Immersion refers to the technical attributes of a system, such as the breadth of sensory input, spatial sound, field of view, and motion tracking (Slater & Wilbur, 1997). Presence, in contrast, describes the psychological perception of being situated within a mediated environment, shaped by the depth of immersion a system provides (Cummings & Bailenson, 2016). Nilsson, Nordahl, and Serafin (2016) extend this framework by

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identifying three dimensions of immersion: technological, narrative, and emotional. This distinction is important for understanding why immersive environments create engagement beyond the capabilities of conventional displays.

Research has demonstrated that immersive environments influence cognitive and emotional processes differently from traditional screens. Brown and Cairns (2004) describe immersion as a progressive process, moving from engagement to deep absorption, which can enhance user attention and focus. Empirical studies further indicate that immersive learning experiences improve knowledge retention and emotional involvement compared to traditional media (Freina & Ott, 2015). For instance, virtual reality applications in education have been shown to increase motivation and learning outcomes by simulating real-world scenarios that demand active participation (Suh & Prophet, 2018).

The interactive potential of immersive environments is another significant factor in their adoption. Unlike conventional screens that rely on indirect input methods such as keyboards or touchscreens, immersive systems integrate gesture control, spatial movement, and haptic feedback, creating more intuitive interaction models (Spittle et al., 2022). The ability to interact naturally within an environment contributes to a stronger sense of presence and engagement, further differentiating immersive environments from traditional displays.

In addition to individual user experiences, immersive environments also facilitate collaborative and social interactions. Unlike traditional screens, which primarily support individual engagement, immersive spaces allow multiple users to share virtual environments, supporting collective interaction and communication (Phillips, 2024). This has implications for areas such as remote collaboration, training, and entertainment, where social presence plays a key role in engagement and effectiveness (Cummings & Bailenson, 2016).

The transition from traditional screens to immersive environments highlights the broader evolution of media interaction. The characteristics of immersive environments – including sensory integration, user interaction, and social collaboration – position them as a development beyond conventional displays. This shift provides the foundation for examining specific immersive formats, such as full dome environments, which further expand the possibilities of interactive and collective media experiences.

3. Why Full Dome is a Key of Future Screen

Full dome technology represents an important evolution within immersive environments, characterized by its unique capability of presenting visual content on a hemispherical screen, thereby offering an experience fundamentally different from conventional screen-based media. Historically originating in planetariums and primarily used for astronomical education, full dome technology has progressively expanded its applications into broader domains including art, scientific visualization, and educational contexts (Díaz, 2011; Lambert & Phillips, 2012). Technologically, full dome distinguishes itself significantly from both traditional and other contemporary immersive displays. Unlike standard two-dimensional screens, which inherently possess framing limitations and restricted visual fields, the hemispherical projection of full dome systems eliminates perceptual boundaries, providing users with a visually continuous and panoramic field of view (Lambert & Phillips, 2012). This panoramic visual environment

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supports spatial immersion by reducing visual distractions, allowing users to engage more uniformly with content, and significantly enhancing spatial cognition and perceptual depth (Schnall, Hedge & Weaver, 2012).

Comparisons between full dome systems and other immersive technologies highlight its unique characteristics. Unlike VR head-mounted displays (HMDs), which offer individual immersion but may induce discomfort due to motion sickness or visual isolation, full dome supports collective experiences, enabling multiple participants to engage simultaneously without the need for wearable equipment (Yu et al., 2017). Compared to CAVE environments, which rely on multiple flat projection surfaces, full dome systems present a unified, continuous display, reducing the segmentation of visual information and maintaining a more cohesive spatial perception (Schnall et al., 2012). This ability to accommodate group-based immersion makes Full dome particularly suitable for applications in education, scientific visualization, and digital arts.

In educational contexts, full dome technology has demonstrated advantages over traditional instructional media. Studies suggest that immersive projection environments improve knowledge retention and conceptual understanding, particularly in disciplines requiring spatial reasoning, such as astronomy and earth sciences (Yu et al., 2017). The all-encompassing nature of full dome visualizations reduces cognitive load by aligning visual stimuli with natural human perception, thus facilitating more intuitive learning experiences. Additionally, the incorporation of dynamic content and real-time simulations in full dome settings has been shown to enhance audience engagement and comprehension (Phillips et al., 2015).

Beyond education, Full dome has been increasingly utilized as a platform for artistic expression. Digital artists and media practitioners have leveraged the medium to explore new forms of immersive storytelling, leveraging its spatial continuity to create non-linear narratives and interactive installations (Phillips et al., 2015). This aligns with broader trends in new media art, where immersion is used as a mechanism for audience participation and experiential engagement. In gaming and interactive experiences, recent developments have sought to integrate real-time input mechanisms, including gesture-based interactions and multi-user engagement models, extending full dome beyond passive viewing towards interactive media formats (Benko & Wilson, 2010).

Despite its advantages, full dome technology faces certain limitations, particularly concerning real-time interactivity. Most of the full dome contents remains pre-rendered, limiting the adaptability of visual output to user inputs (Phillips, 2024). Advances in AI and sensor-based interaction models, including physiological signal integration, have been proposed as solutions to enhance interactivity. Emerging research explores the use of EEG and biometric feedback to enable real-time content modulation based on cognitive and emotional responses (Kovacevic et al., 2015). Such developments suggest a trajectory in which Full dome environments transition from passive viewing systems to dynamic, responsive media platforms, further solidifying their role within the evolution of immersive screen technologies.

4. Why EEG + Full Dome is a Future Screen

The integration of EEG with full dome technology represents a significant advancement in immersive screen environments, enhancing both interactivity and adaptability. Traditional full dome projection systems have historically re-

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lied on pre-rendered content; however, recent advancements in computational workflows, such as those integrating Unity3D for real-time mesh warping, have enabled greater adaptability (Melenbrink & King, 2015). EEG-based systems provide a means of incorporating real-time physiological feedback, allowing for dynamic adjustments to visual and auditory stimuli based on cognitive and emotional states (Yu et al., 2022; Weinel et al., 2014). This integration aligns with broader trends in interactive media, where adaptive content systems enhance immersion and user experience through direct biological interaction.

EEG functions by recording electrical activity in the brain, offering insights into user attention, cognitive load, and emotional states (Picard, 1997). Research indicates that EEG signals, particularly within theta (4-8 Hz) and gamma (30-49 Hz) frequency bands, are strongly correlated with emotional responses in immersive environments (Yu et al., 2022; Kober et al., 2012). The capacity to analyze such signals in real time enables a full dome system to adjust its content dynamically, modulating aspects such as brightness, color, movement speed, and visual complexity to enhance user engagement (Kovacevic et al., 2015). Compared to traditional interaction methods, which rely on explicit user commands, EEG-based systems enable implicit, subconscious interaction, fostering a more seamless and personalized immersive experience (Kovacevic et al., 2015).

The use of EEG within immersive environments has been extensively explored in VR research. Studies have demonstrated that EEG can effectively measure presence and engagement levels, offering a reliable metric for evaluating immersive experiences (Tauscher et al., 2019; Kober et al., 2012). However, EEG integration within VR remains constrained by hardware limitations, particularly the physical interference of head-mounted displays with EEG sensors. Full dome environments, by contrast, eliminate the need for direct head-mounted equipment, providing a setting where EEG data can be collected with fewer artifacts and signal disruptions (Tauscher et al., 2019; Weinel et al., 2014). This suggests that full dome systems may serve as an optimal platform for EEG-driven interactive content, overcoming some of the limitations inherent in VR-based EEG applications.

Beyond measuring engagement, EEG technology facilitates real-time emotional adaptation within full dome environments. Adaptive systems leveraging EEG data have demonstrated the ability to personalize user experiences by responding to shifts in cognitive and emotional states (Yu et al., 2022; Weinel et al., 2014). For example, heightened cognitive load or stress levels, as indicated by EEG readings, could trigger adjustments in visual intensity or auditory complexity to maintain an optimal state of engagement (Kober et al., 2012). Such advancements align with research on EEG-based neurofeedback, which has been applied to therapeutic and training contexts, demonstrating the potential for full dome systems to evolve into interactive cognitive and emotional training environments (Kovacevic et al., 2015).

The integration of EEG with full dome technology also enables the development of collective adaptive experiences. Whereas VR-based EEG interactions are largely individualized, full dome environments allow for simultaneous EEG monitoring across multiple users, enabling content to adapt based on aggregated emotional responses (Kovacevic et al., 2015; Yu et al., 2022). Such applications extend to fields such as group meditation, collaborative learning, and synchronized audience-driven narratives in digital performance spaces (Weinel et al., 2014; Kober et al., 2012).

As immersive screen technologies advance, EEG integration presents a pathway for full dome environments to transition from passive viewing systems to dynamic, user-re-

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sponsive platforms. By leveraging real-time physiological feedback, full dome systems can provide a more personalized and interactive experience, surpassing the constraints of traditional pre-rendered content. Future research should explore the combination of EEG with AI to enhance adaptive capabilities, enabling more sophisticated real-time adjustments based on complex cognitive and emotional patterns (Du et al., 2024; Weinel et al., 2014). This convergence of EEG, AI, and immersive media positions full dome as a key component in the evolution of future screen technologies.

5. Experimental Project: Coids

5.1. *Conceptual Background*

Coids (Cosmic-oid Objects) is an interactive full dome project that investigates how human emotional states can be translated into generative visual forms through the integration of EEG data and AI. The work is motivated by a central question: In the context of AI-generated visual content, can human emotion remain an active and meaningful driver of image generation?

The project combines physiological sensing with real-time audiovisual feedback to construct an immersive system in which viewers' affective states – captured via brainwave signals – directly influence the visual content projected inside a full dome environment. Rather than relying on explicit interaction mechanisms such as touch or speech, Coids engages with non-verbal, physiological input, creating a system where emotional responses contribute to the generative process itself.

The title Coids is derived from "Boids", a behavioral simulation model used in computer graphics to depict flocking behavior (Hartman & Benes, 2006). By extending this concept from biological motion to affect-driven particle dynamics, Coids reframes the original algorithm in a different context: instead of modeling flocking behavior among agents, it explores how emotional states can influence collective visual behavior at a cosmological scale.

The core idea of the project is to represent emotion not symbolically, but structurally – by mapping affective input to visual parameters such as color, motion, and speed within a dynamic particle system. These particles are derived from AI-generated imagery based on astronomical references, including nebulae and cosmic phenomena, evoking a sense of scale that links inner psychological states with outer spatial environments.

Coids therefore positions emotional data as a real-time modulator of visual experience, highlighting a form of interaction that is intimate, continuous, and non-verbal. By embedding physiological feedback within an immersive visual system, the project proposes a new mode of audience engagement – one that shifts from active control to affective co-presence.

5.2. *System Design*

5.2.1. EEG Signal Acquisition and Emotion Classification

In this project, EEG data is acquired using the Muse 2 headband, a consumer-grade device equipped with four dry electrodes (TP9, AF7, AF8, TP10) and one reference sensor.

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Figure 1. A view of the Coids exhibit in Market Hall's Dome Theater, 2025 (©and Photo: Yuming Chen).

The Muse 2 is favored for its portability and ease of integration into real-time audiovisual systems (Krigolson et al., 2021). Brain signals are transmitted via the Mind Monitor application, which streams raw frequency-band data into TouchDesigner, where signal processing and visualization are performed.

In order to reduce noise and computational complexity while maintaining the reliability of emotion signals, only the AF7 and AF8 channels located in the prefrontal cortex are used for emotion analysis. These channels have been shown to be very sensitive to emotional and arousal-related brain activity, especially in the alpha, beta, and theta bands (Bird et al., 2018).

Since Muse 2 does not provide separate frequency bands for individual channels, we implemented a Fast Fourier Transform (FFT) via Python script in TouchDesigner. This enables real-time decomposition of continuous EEG signals from AF7 and AF8 into alpha (8-12 Hz), beta (13-30 Hz) and theta (4-7 Hz) components. Following the methodology described by Bird et al. (2018), the emotional state is estimated by computing power spectral features for each frequency band over sliding time windows (1-second window with 50% overlap). Specifically, the following features are extracted:

- Mean band power in alpha, beta, and theta ranges.
- Asymmetry between AF7 and AF8 band powers.
- Alpha/beta and theta/beta ratios, commonly used indicators for arousal and attention levels.

The affective dimensions are then estimated as follows:

- *Valence* is approximated using alpha asymmetry:

$$Valence = P_{\alpha}^{AF7} - P_{\alpha}^{AF8}$$

Greater left-frontal alpha activity (lower AF7 alpha power) is associated with more positive emotional valence (Bird et al., 2018).

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- Arousal is computed as a composite of beta and theta activity, often using a ratio such as:

$$Arousal = \frac{P_{\beta}^{AF7} + P_{\beta}^{AF8}}{P_{\theta}^{AF7} + P_{\theta}^{AF8}}$$

These heuristics are derived from prior EEG studies in affective computing and brain-machine interfaces, and have shown effectiveness even with low-density EEG systems such as Muse (Bird et al., 2019).

The resulting valence and arousal values are mapped to visual parameters in the generative system, enabling the audience's real-time emotional states to directly shape the immersive audiovisual experience.

5.2.2. Affective-to-Visual Mapping Strategy

To translate emotional states into visual experience, Coids employs a dual-channel mapping system: one that links affective states to text-based prompt control for AI-generated image, and another that modulates particle behavior in a custom-built system within TouchDesigner. Both are continuously updated based on the user's real-time valence and arousal values derived from EEG signals.

Emotionally reactive imagery is generated through a custom integration of Stable Diffusion into TouchDesigner, using an API-based interface. To adapt the model to the aesthetic scope of the project, LoRA fine-tuning is performed using publicly available astronomical datasets from NASA, allowing the model to specialize in generating cosmic visual textures such as nebulae, stellar clusters, and gravitational fields.

Emotional dimensions are mapped to semantic prompt modifiers, based on the circumplex model of affect (Russell, 1980). For instance:

- Positive valence (e.g., relaxed, joyful) prompts visual keywords such as warm galaxy, soft aurora, or glowing nebula (Nijdam, 2005).
- Negative valence (e.g., anxious, tense) generates cold space, dark matter storm, or fragmented starlight (Nijdam, 2005).
- High arousal strengthens adjectives like swirling, exploding, or intense, while low arousal evokes drifting, dissolving, or ambient.

This dynamic prompt modulation results in real-time AI-generated visuals that reflect the emotional landscape of the participant in a way that is both semantically coherent and emotionally resonant.

In parallel to prompt generation, the valence and arousal values also control visual parameters within a procedural particle system developed in TouchDesigner. Specifically:

- Valence is mapped to the color gradient of particles:
  - Positive valence is expressed through warm colors (e.g., gold, red-orange, pink), associated with joy, affection, and vitality (Kaya, 2004).
  - Negative valence shifts the palette toward cool or muted tones (e.g., blue, grey, violet), associated with calmness, sadness, or detachment (Kaya, 2004).

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- Arousal is mapped to the kinetic properties of the particle system:
  - High arousal increases velocity, turbulence, and diffusion radius, creating dynamic, chaotic, and energetic visual behavior.
  - Low arousal results in slower, more cohesive flows, evoking serenity and spaciousness.

To adapt to the unique geometry of the full dome environment, the generative visuals are structured around radial symmetry and circular transformations, echoing the participant's emotional dynamics. The central metaphor is the transition from rings to spheres – representing the shift from individual inner experience to a shared emotional cosmos. These visual transitions not only serve spatial composition but also function as symbolic expressions of emotional expansion and collapse, synchronizing body and environment.

Due to hardware limitations, a single Muse 2 headset, only one participant can engage with the system at a time. However, to ensure perceptual coherence and avoid visual "flickering" caused by rapid emotional shifts, a temporal smoothing algorithm is implemented. Valence and arousal values are updated with a weighted moving average, ensuring gradual transitions and sustaining immersive continuity.

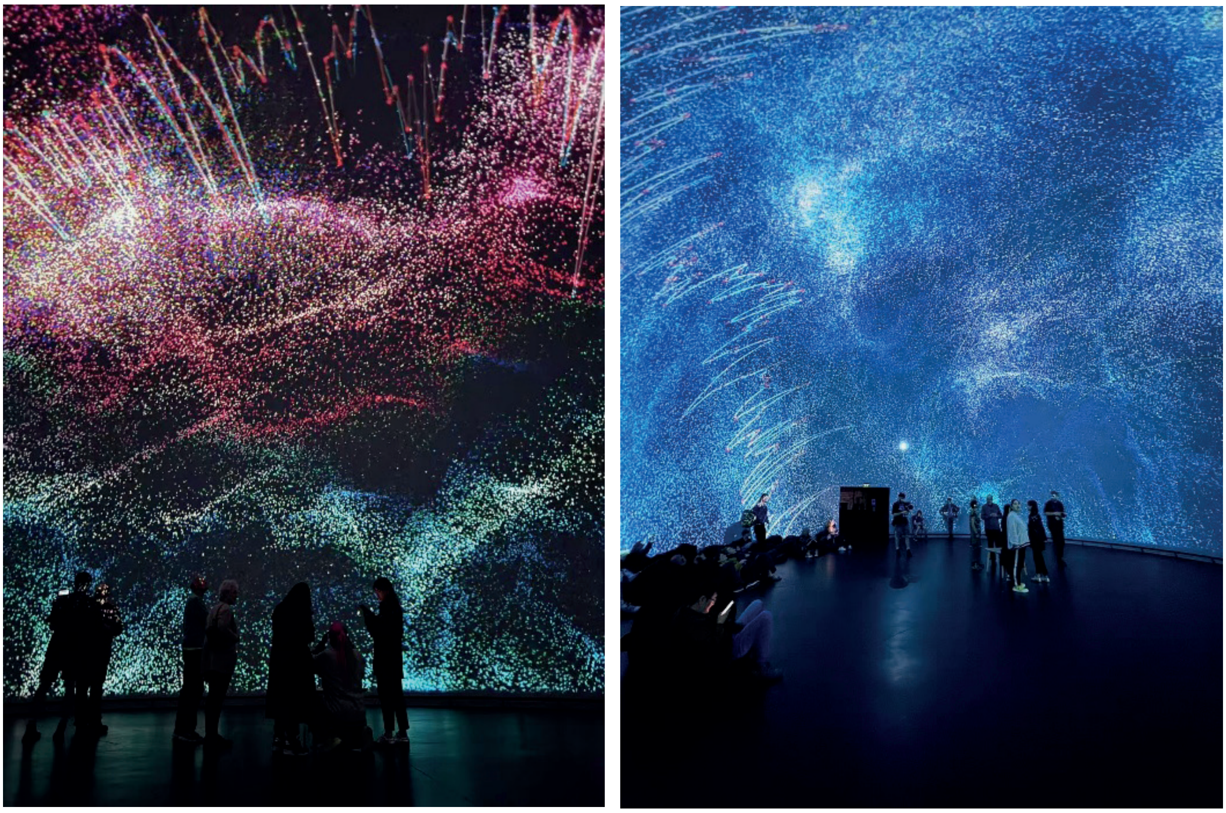

Figure 2. Different emotions presented by Coids, 2025 (©and Photo: Yuming Chen).

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Figure 3. Audience wear Muse 2 to transmit emotions to the Coids system., 2025 (©and Photo: Yuming Chen).

5.3. *Audience Experience*

The first public presentation of Coids took place on 9 April 2025 at Market Hall, Plymouth. The work was shown inside a 15-meter diameter full dome theater. Around 150 visitors attended throughout the day. Each was invited to engage with the installation individually using the Muse 2 EEG headset.

The real-time interaction was central. Brainwave data influenced AI-generated visuals instantly, creating a direct feedback loop between mind and image. This immediacy reflects a key shift in Future Screen practices – from static, pre-rendered content to environments that respond to human presence, emotion, and cognition. The exhibition offered insights into how audiences engage with this kind of responsive, emotionally-driven system.

Feedback collected during the event indicated that audiences were generally intrigued by the responsive and personalized nature of the experience. Many visitors described the system as a notable departure from traditional full dome works, which are typically linear and non-interactive. In contrast, Coids enabled viewers to witness how their emotional states could shape the surrounding visual field in real time, thus encouraging a stronger sense of engagement and emotional presence.

However, the exhibition also revealed some technical limitations. Due to the sampling frequency of the Muse 2 device and the Bluetooth transmission method, as well as factors affecting the Muse 2 device such as the presence of the participant's own frown (Díaz De León et al., 1988), there was a delay of approximately 5 seconds between the participant's actual emotional state and the corresponding visual response. In addition, according to participants' self-reports in the post-experience questionnaire, the average error rate of EEG-based estimates of emotional states was approximately 30%.

Despite this delay and recognition inaccuracy, the majority of participants reported that it did not negatively affect their interest or enjoyment. On the contrary, they expressed strong curiosity and appreciation for the novel integration of EEG, generative

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AI, and full dome projection. The audience's responses suggest that technical imperfections were perceived as acceptable trade-offs within the context of an experimental artistic environment.

Furthermore, the project encouraged social interaction within the dome space. While only one user could engage with the system at a time, others observed the changing visuals and often engaged in conversation about the relationship between emotion and imagery. This collective setting allowed Coids to function not only as a solo interface but also as a shared emotional and discursive space.

Fig. 4. Audience members shared their emotional experiences with each other, 2025 (©and Photo: Yuming Chen).

6. Conclusion

This research examined the integration of EEG-based emotion recognition and AI-generated visuals within full dome environments as a novel approach to interactive screen-based media. By situating this integration within the broader discourse on immersive technologies and the evolving concept of the "Future Screen", the study highlights the potential of bio-responsive systems to enhance presence, personalization, and audience engagement in collective visual experiences.

The implementation of Coids served as a practice-based investigation into the technical and experiential affordances of affective, real-time media systems. Findings from its public deployment indicate that emotional input, captured via accessible EEG hardware despite limited signal resolution, can be effectively mapped onto generative visual output within immersive environments. While constraints such as signal latency, classification inaccuracy, and a single-user configuration remain, audience responses suggest that the system's perceived responsiveness and emotional resonance significantly contributed to the immersive experience.

These findings point to a set of defining characteristics for Future Screen environments: immersive spatial display, real-time human-machine interaction, affective responsiveness, and adaptive visual generation. Coids demonstrates how these features can be materially realized through the convergence of brain-computer interfaces, AI-driven visual systems, and dome-based projection technologies.

Moreover, the results suggest that EEG-driven interaction may constitute a viable framework for extending the interactive potential of full dome systems beyond conven-

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tional input modalities. The integration of affective computing with generative AI enables a shift from symbolic commands to continuous, non-verbal modulation of audiovisual space – an approach with particular relevance for digital art, affective learning, and therapeutic media contexts.

Future research should address current limitations through improved signal processing, more robust emotion classification algorithms, and support for multi-user interaction. Further investigation is also required to explore how emotional data can be interpreted and integrated within collective experiences without compromising individual specificity or coherence. Ultimately, the convergence of immersive media, physiological sensing, and computational creativity offers promising new directions for understanding and designing Future Screen experiences as adaptive, affective, and socially situated systems.

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