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DESIGNING FOR WONDER: A NEURO-ARCHITECTURAL ANALYSIS FRAMEWORK (NAAF) FOR INVESTIGATING EXPERIENCE IN DESIGN HAPPENINGS

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Abstract

This paper introduces the neuro-architectural analysis framework (NAAF), a design-research-driven system that integrates mobile EEG (MoBI) with design-ethnography and smart building sensor data to provide a comprehensive assessment of the whole human experience within dynamic social spaces. Situated within an urban design research lab, the NAAF is tested and developed through "Design Happenings" (participatory, sensory events modeled after Allan Kaprow's art "Happenings") that serve as a testbed for investigating wonder as a sustained, curiosity-driven, affective-cognitive state. By introducing a wireless electroencephalography (EEG) headset, specifically the *g.tec Unicorn Hybrid Black*, to capture brain-computer interface (BCI) data including time-resolved neural indicators of attention and arousal in situ, a critical "experiential gap" in current architectural and design research is filled. The NAAF is developed on a pragmatic-phenomenological theoretical foundation and enriched through principles of architectural experience design, humanistic psychology, and neuroaesthetics. The NAAF enables interdisciplinary teams to develop constructed environments that not only support physical safety and function but also create experiential value and holistically serve human, and more-than-human, well-being.

Keywords: *Design happenings, design research, EEG, mobile brain/body imaging (MoBI), neuroarchitecture.*

1. Introduction

Iconic architects Louis Kahn, Tadao Ando, and Shigeru Ban have expressed that architecture must be "unmeasurable," engage body and mind, and that even temporary buildings can be made permanent -if people love them (respectively). Fundamental to architecture are the Vitruvian requirements of *Firmitas* (stability), *Utilitas* (utility), and the psychophysical experience of *Venustas* (delight) - a principle closely connected to contemporary concepts of wonder and eudaimonic wellbeing (Coburn et al., 2020); (Daum, 2019). Given these demands, how do we measure 'delight' in architecture? In contemporary architectural practice, smart-building technologies utilize sensor networks to optimize environmental performance and hedonic comfort, monitoring variables like temperature, air quality, and user occupancy (Schwee et al., 2019); (Coulby, G., Clear, A., Jones, O., & Godfrey, A. 2020). These systems rely on proxy-based inference and lack the contextual data to capture how an environment is actually "felt" or how it facilitates deep engagement (Cahill et al., 2019). While design-ethnographic research compliments smart-building sensor data by observing natural behaviors and social context, it often lacks temporal precision (Mavros, Austwick, & Smith 2016).

To bridge this "analytical gap," and built on a *Pragmatic-Phenomenological* theoretical foundation, the Immersive Design Research Lab is integrating Mobile Brain/Body Imaging (MoBI) with smart-building technologies and design-ethnography as a neuro-architectural analysis framework (NAAF) (Barker 2019). This framework structures the capture of natural cognition in action where perception and environment are tightly coupled (Gramann, Ferris, Gwin, & Makeig 2014); (Jungnickel & Gramann 2016). While smart-building technologies already measure human comfort and systems' efficiency, they don't capture how environments are experienced. Through design-ethnography, we gain some insight into presence, engagement, and meaning. MoBI adds a complementary data layer indicating attention and engagement shifts during real-world architectural and design experiences. The goal of this work is to extend in situ architectural and design assessment methods to capture the whole human experience (Vartanian et al., 2013); (Krugliak & Clarke, 2022).

2. Objectives

Design and architecture are pragmatic, phenomenological, and ethically accountable practices; they shape wellbeing, from short-term hedonic comfort (pleasure and safety) to long-term eudaimonic flourishing (meaning and engagement) (Ryff, Boylan, & Kirsch, 2021). In order to design for the whole human experience, a means to assess the psychophysical impacts of the constructed environment, as a tool of continuous improvement, is required. Through the lens of neuroaesthetics, these experiences are modeled through an aesthetic triad of neural systems: knowledge-meaning, emotion-valuation, and sensorimotor- which process how the built environment impacts our senses and sensibilities (Chatterjee, 2011). For example, experiencing architectural awe (frequently a goal of religious, institutional, or cultural buildings) is often a disarming, overwhelming response to scale that results in a "small self" and a need for cognitive accommodation (van Elk, Arciniegas Gomez, van der Zwaag, van Schie & Sauter, 2019).

Wonder, in contrast, is a sustained state of curiosity and rapt attention that facilitates deeper embodied participation, is an engaging, exploratory re-orientation of self-in-world, and state of attentional modulation and active sense-making (Shiota, Keltner, & Mossman, 2007); (Gallagher, Reinerman-Jones, Janz & Sollins, 2015); (van Elk, et al., 2019); (Keltner & Haidt, 2003); (Raichle, et al., 2001). By creating immersive prototype environments, we go beyond system-centered efficiency and are intentionally designing for transformative sensory and psychological experiences (Kaprow, 2003); (Boczar, Montrosse-Moorhead & Davidesco, 2025).

2.1. Designing for wonder

We design for wonder for the following key reasons:

- Cognitive Transformation: Wonder acts as a catalyst for transformative insight, creating a tension between sense experience and intellectual judgment. It disrupts automatic thinking patterns and opens cognitive space for new ideas and reordered conceptual frameworks. Historically, wonder is recognized as the foundation of philosophy and science (Daum, 2019); (Guan, Xiang, Chen, Wang, & Chen, 2018).
- Social Connection: Wonder encourages embodied participation and generative knowledge production, helping individuals feel integrated into a "bigger whole" and fostering prosocial relationality (Gallagher et al., 2015); (Graziosi & Yaden, 2019); (Morgan et al., 2022).
- Disruption of the Status Quo: Neuroscientifically, the maintenance of a cognitive or sensorimotor status quo is associated with beta-band oscillations (BBA). We design sensory "features" to defamiliarize and disrupt these patterns to achieve a state of wonder, signaling a readiness to process novel information (Shiota, et al., 2007); (Chirico & Yaden, 2018); (Engel & Fries, 2010).
- Health "Repair": As a self-transcendent emotion, wonder facilitates "unselfing," a process that diminishes ruminative self-focus and is associated with reduced sympathetic arousal and inflammation (Monroy & Keltner, 2023); (van Elk et al., 2019).

Designing for wonder demonstrates ethically responsible practice, serving the whole of human well-being.

3. Materials and methods

The NAAF aligns three complementary modalities to assess the whole human experience:

1. Smart Building Sensing: Monitors environmental performance and physical comfort (Coulby et al., 2020); (Schwee et al., 2019).
2. Mobile EEG (MoBI): Captures time-locked indicators of attention dynamics and affective arousal in real-world settings (Jungnickel et al., 2016); (Gramann et al., 2014); (Gramann, 2024).
3. Design-Ethnography: Captures lived experience, social resonance, and contextualized meaning-making through multi-modal documentation, situated field notes, and participant reflection (Cahill et al., 2019).

Mobile EEG Implementation (per the literature and *g.tec* guidelines): Data are to be acquired using the *g.tec Unicorn Hybrid Black*, an 8-channel wireless system. The montage (Fp1, Fp2, Fz, Cz, Pz, P3, P4) prioritizes frontal-central-parietal coverage to capture dynamics associated with attentional engagement and environmental attunement. Data are sampled at 250 Hz (24-bit resolution) with a 0.1-40 Hz band-pass filter. Consistent with MoBI practices, data quality is evaluated in relation to ecological validity rather than laboratory purity (Jungnickel et al., 2016); (Gramann, 2024).

Table 1. Neuro-Architectural Analysis Framework (NAAF): Three complimentary modalities for assessing architectural and design experiences. Smart-building and environmental sensing systems provide robust measures of environmental performance and comfort-related wellbeing. Mobile EEG is introduced to provide time-resolved indicators of attentional and affective dynamics during real-world experiences. Design-ethnographic methods capture lived experience, meaning-making, and social engagement. Together, these modalities support a more comprehensive assessment of the whole (more than) human interactive design and architectural experience.

	Smart Building & Environmental Sensing	***Mobile EEG (MoBI) Data Capture***	***Design- Ethnographic Assessment***
Application	*Advanced Building Research and Practice*	***Experiential Research Gap***	*Advanced Design Research and Practice*
Well-Being	*Hedonic (pleasure and safety)*	*Bridging Hedonic and Eudaimonic (attention)*	*Eudaimonic (meaning and engagement)*
Primary Focus	*Comfort (Bodily)* *Safety (Physical)* *Energy and Systems Optimization*	*Attention Dynamics* *Affective Arousal* *Experiential Transitions*	*Affective Engagement* *Embodied Participation* *Experiential Resonance*
Primary Tools	*Environmental Sensors (temperature, humidity, light, sound, air quality)* *Occupant Movement Tracking* *Energy and Technology Systems Monitoring*	*Portable EEG (eg. g.tec Hybrid Black, Unicorn EEG)* *Time-locked Event Markers* *Synchronized Movement, Spatial, and Sensing Logs*	*Human+ Participant Monitoring (direct, in-situ video capture, wearables)* *Interviews, Surveys, and Reflective Commentary,* *Behavioral and Social Mapping*
Data Type	*Environmental Performance*	*Neural Dynamics*	*Contextual Meaning and Culture*
Data Characteristics	*Aggregate* *Continuous* *Proxy-Based Inference* *System-Centered*	*Event-Based* *Noisy* *Time-Resolved* *Physiological*	*Contextualized* *Experience Centered* *Interpretive* *Multi-Modal*
Limitations	*Does not capture:* *Motivations* *Productivity* *Psychological Impact*	*Does not:* *Attribute Meaning* *Decode Emotions* *Diagnose Conditions*	*Does not capture:* *Ecological Validity* *Interpretive Bias* *Participant Mental State*
NAAF Integrated Whole Human Experience Assessment of Architecture and Design Engagement			

The NAAF is an integrated methodological framework used to investigate ‘wonder’ in the context of architectural and design experiences; prototyped through Design Happenings in an urban design research lab. Environmental sensing is augmented through design-ethnographic observation and participant reflection which form the interpretive foundation, while mobile EEG provides a complementary layer capturing attentional dynamics during lived spatial engagement. The framework emphasizes triangulation and explicitly limits interpretation, positioning EEG as an evaluative tool rather than a diagnostic or causal instrument.

4. Preliminary observations and expected results

The Immersive Design Research Lab (IDRL) has implemented three Design Happenings in its new downtown location. Focusing on design-ethnographic methods, researchers have observed consistent experiential patterns: prolonged attention and sensory engagement with "features", openness to interaction with strangers, slowed physical movement, dwelling, and social clustering (Kaprow, 1969). Initial testing of the MoBI system is expected to reveal specific neural modulations:

- Spatial transitions leading to observed pauses are expected to correlate with theta-band activity (4–7 Hz) related to cognitive control and the realization of a need for engagement (Cavanagh & Frank, 2014).
- Social clustering is expected to produce sustained attention patterns discernible in time-resolved physiological data.
- Beta-band modulation (13–30 Hz) is expected to signal the disruption of the cognitive status quo when constituents encounter sensory "features". EEG is not used to detect wonder or specific emotions; interpretation requires a priori ethnographic context to attribute meaning to neural dynamics (Debener, Minow, Emkes, Gandras & de Vos, 2012); (Engel & Fries 2010); (Gramann, 2024).

5. Discussion

This work establishes a methodological pathway for studying dimensions of design otherwise inaccessible through typical tools. By integrating MoBI with smart-building sensors and ethnography, we fill a precise epistemic gap. While awe dominates current scientific literature due to its intensity and laboratory inducibility, wonder is more architecture and design-practice relevant as a slower-forming, sustained state (Gallagher, Reinerman-Jones, Janz & Sollins, 2015); (Shiota et al., 2007).

Humanistic psychology legitimizes the framework's prioritization of agency and subjective experience. EEG data is introduced, subordinated to lived experience, as time-locked neural variation - only meaningful when situated within a broader phenomenological and social context. The NAAF represents a beginning for interdisciplinary neuro-architectural collaboration, providing a shared language for designers, psychologists, and neuroscientists developing places of experiential wellbeing. Ultimately, the NAAF fills an epistemological gap for developing experiential environments that are "unmeasurable", experienced by body and mind, and loved by the agents that engage with them - making the constructed environment more durable, sustainable, valuable, and culturally relevant.

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