Biometric Measures of Stress in Trauma-informed and Conventional Spaces Using VR, Eye Tracking, and Wearable Sensors

Trauma-informed Design Society

A planned multimodal pilot study bridging Trauma-informed Design, Neuroarchitecture, and Mobile Brain/Body Imaging

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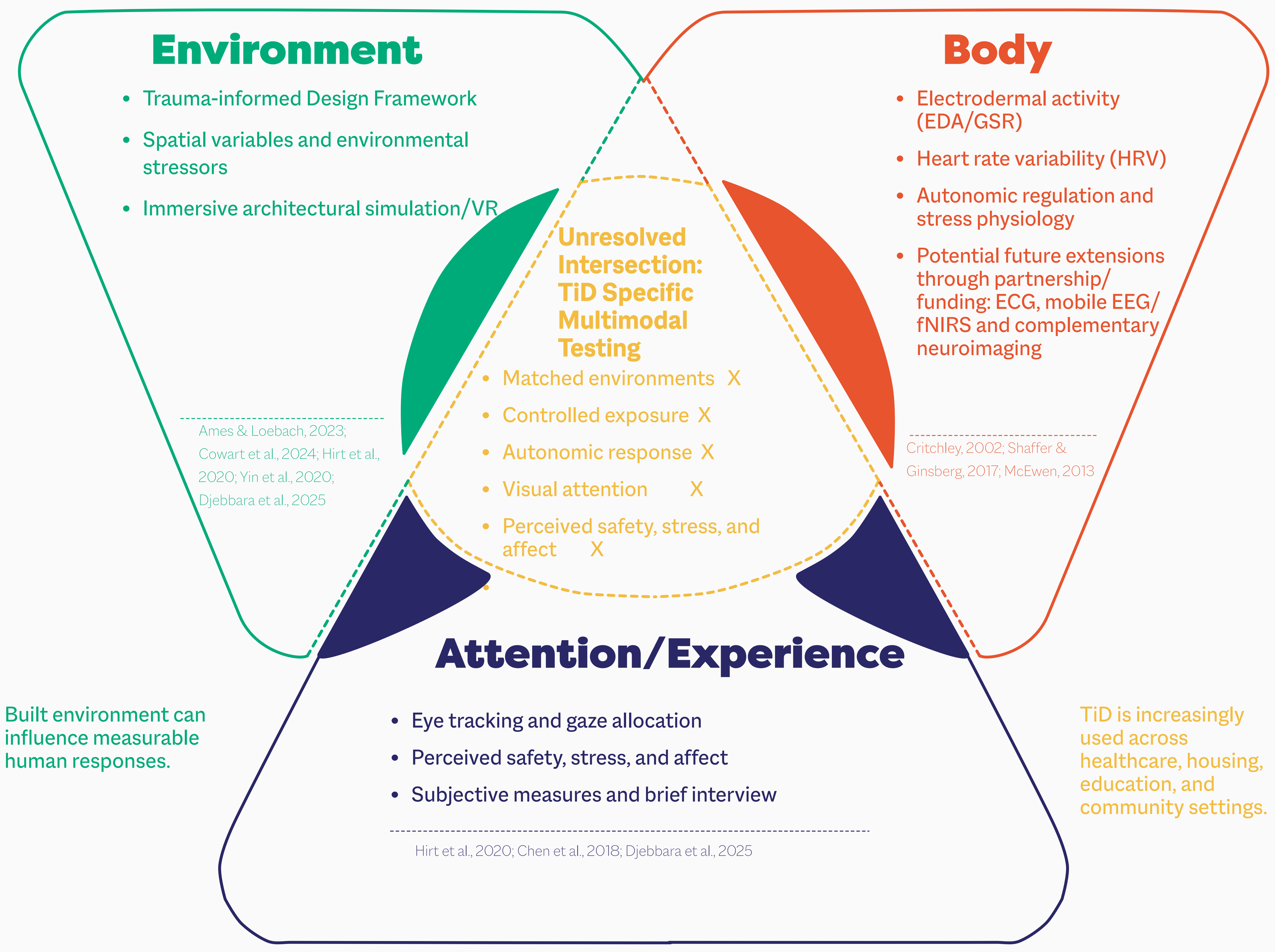
1 BACKGROUND & RATIONALE

The built environment is increasingly recognized as a health-relevant exposure that can shape psychological experience, physiological regulation, behavior, and perceived safety. Environmental characteristics may support or undermine mental health and wellbeing (Beemer et al., 2021). Trauma-informed Design (TiD) extends trauma-informed care into the built environment by seeking to reduce environmental stressors while supporting autonomy, identity, empowerment, and perceived safety (Ames & Loebach, 2023; Cowart et al., 2024). Stress is therefore a relevant construct for TiD research because environmental conditions may contribute to both perceived safety and physiological regulation. Intense or prolonged stress can disrupt neural, neuroendocrine, immune, and cardiovascular processes, providing one pathway through which adversity may have lasting effects on health and wellbeing (McEwen, 2013). Environmental conditions may therefore amplify stress responses or support regulation, particularly for individuals with heightened stress responsivity or histories of trauma.

Environmental psychology and neuroarchitecture increasingly use heart rate variability (HRV), electrodermal activity (EDA), eye tracking, wearable sensors, and immersive simulation to capture moment to moment autonomic and attentional responses under controlled exposure (Chen et al., 2018; Hirt et al., 2020; Yin et al., 2020). Yet TiD specific spatial strategies have rarely been operationalized experimentally and examined through synchronized physiological, oculomotor, and subjective measures. This planned pilot addresses that gap by combining immersive architectural simulation, eye tracking, autonomic measures, and subjective assessment to compare responses to matched Trauma-informed and conventional environments.

2 CONVERGENCE MAP & THE GAP IN LITERATURE

Existing literatures provide evidence within environmental, physiological, and experiential domains, but their integration remains limited, particularly for synchronized testing of Trauma-informed Design.



3 RESEARCH QUESTION & ANALYTIC OBJECTIVES

PRIMARY RESEARCH QUESTION

How do matched Trauma-informed and conventional architectural environments differ in the patterns of physiological regulation, visual attention, and perceived safety they elicit during controlled immersive exposure, and how are those responses associated with specific spatial features?

OBJECTIVES

- Operationalize elements of the Trauma-informed Design Framework as experimentally controlled spatial variables within matched architectural environments, while holding program, scale, viewpoint, exposure duration, and other non-target characteristics as consistent as feasible.
- Characterize within-participant multimodal response patterns across Trauma-informed and conventional conditions using autonomic measures, eye tracking, and subjective assessments of perceived safety, stress, affect, and environmental experience.
- Examine spatial and temporal relationships between environmental features and human response, including whether gaze allocation and changes in physiological arousal coincide with particular architectural areas of interest (AOIs) or moments of exposure.
- Evaluate convergence and divergence across modalities to determine whether physiological, attentional, and self-reported responses provide complementary or conflicting accounts of environmental experience.
- Establish the methodological feasibility of the integrated protocol, including participant tolerance, signal quality, synchronization accuracy, exposure duration, data completeness, and variance estimates needed to refine the design of a larger study.

4 WHY MoBI? METHODOLOGICAL & SCIENTIFIC CONTRIBUTION

METHOD

Develop and test a synchronized multimodal protocol for controlled architectural exposure.

SCIENCE

Connect environmental design with physiological, attentional, and experiential response at the level of specific spatial features.

TiD

Translate elements of the TiD Framework into experimentally manipulable spatial variables and begin testing their measurable human-response correlates.

PRACTICE

Establish a pathway toward evaluating proposed environments before construction and, ultimately, validating findings in real-world settings.

5 PROPOSED EXPERIMENTAL FRAMEWORK & WITHIN-SUBJECT PROTOCOL

TRAUMA-INFORMED DESIGN FRAMEWORK

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OPERATIONALIZE TiD PRINCIPLES AS TESTABLE SPATIAL VARIABLES

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DEVELOP MATCHED EXPERIMENTAL ENVIRONMENTS

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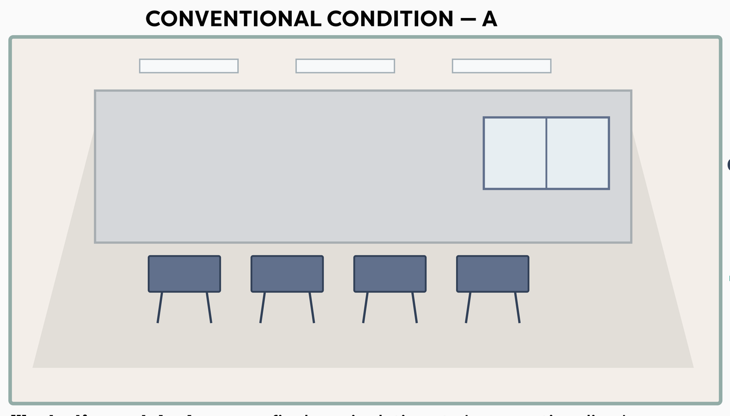
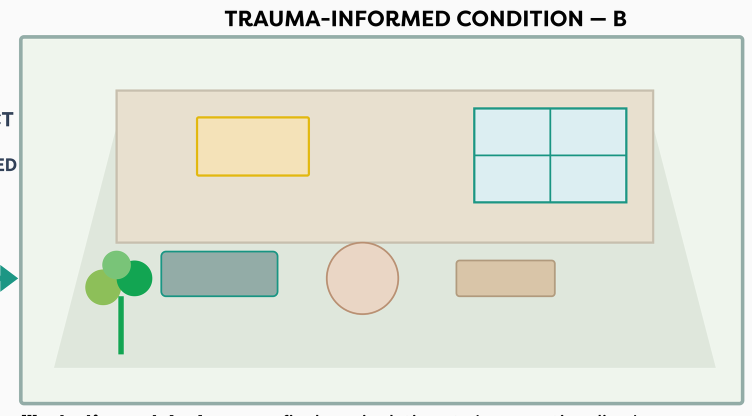
CONVENTIONAL CONDITION — A



Illustrative matched scene — final manipulations to be operationalized
Controlled where feasible: program • overall scale • viewpoint • exposure duration

WITHIN-SUBJECT COUNTERBALANCED EXPOSURE →

TRAUMA-INFORMED CONDITION — B



Illustrative matched scene — final manipulations to be operationalized
Controlled where feasible: program • overall scale • viewpoint • exposure duration
Manipulated: selected TiD-relevant spatial variables

ONE-VISIT PROTOCOL

Consent + Baseline → Sensor setup + Calibration → Condition A/B → Recovery / Washout → Condition B/A → Post measures + Interview

SYNCHRONIZED MULTIMODAL ACQUISITION

ENVIRONMENT	PHYSIOLOGY	ATTENTION	EXPERIENCE
Condition • feature • AOI • Event / exposure timing	EDA/GSR • HR/HRV • Autonomic Arousal/Regulation	Fixation • Dwell • Gaze • Spatial AOIs	Safety • Stress/Affect • Comfort/Presence • Interview

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TIME-SYNCHRONIZED MULTIMODAL INTEGRATION

WHERE? + WHEN? + WHAT feature? + HOW was it experienced?

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ENVIRONMENTAL FEATURE ↔ RESPONSE MAPPING

6 ANALYTIC STRATEGY, EXPLORATORY HYPOTHESES & PILOT FEASIBILITY

1. ANALYTIC STRATEGY

- Compare within-participant responses across matched TiD and conventional conditions.
- Conduct event-aligned analyses linking environmental features and AOIs with changes in gaze and autonomic response.
- Examine fixation, dwell, and gaze-allocation patterns across spatial areas of interest.
- Evaluate convergence and divergence among physiological, attentional, and subjective response streams.
- Explore environmental feature ↔ response associations rather than treating each modality independently.

2. EXPLORATORY HYPOTHESES

- H1 — TiD conditions will show distinguishable autonomic response profiles relative to matched conventional conditions.
- H2 — Gaze allocation and dwell patterns will differ between conditions, particularly around manipulated spatial features.
- H3 — TiD conditions will be associated with higher perceived safety and more favorable stress/affective responses.
- H4 — Physiological, attentional, and subjective responses will show partial rather than complete convergence.

3. PILOT FEASIBILITY & SCALING

- VR tolerance and participant comfort
- Biometric and eye-tracking signal completeness/quality
- Synchronization accuracy across streams
- Adequacy of baseline, exposure, and recovery periods
- Calibration and artifact burden
- Clarity and sensitivity of subjective measures
- Feasibility of defining meaningful spatial AOIs and event markers
- Variance estimates and procedural lessons to inform the design of the larger study

PILOT OUTPUT

Refined multimodal protocol + synchronization and signal-quality parameters + candidate environmental feature response markers + variance estimates to inform future sample-size planning and multi-site validation

7 COLLABORATION OPPORTUNITY & IMPLEMENTATION NEEDS

This planned pilot is being developed at a stage where the research question, Trauma-informed Design Framework, proposed environmental conditions, and multimodal measurement strategy are defined, but data collection has not yet begun. This creates an opportunity to refine the protocol collaboratively before implementation, particularly around sensor integration, synchronization, experimental control, eye-tracking and physiological analysis, and the translation of Trauma-informed Design principles into testable spatial variables. The study therefore seeks methodological and institutional partners with expertise in MoBI, psychophysiology, immersive VR/XR, eye tracking, multimodal analysis, or real-world study implementation.

The current team brings the Trauma-informed Design Framework, architectural research question, environmental-design expertise, VR experience, and a pathway to practice; scientific collaborators could strengthen the experimental methodology, research infrastructure, and eventual validation of the protocol. Implementation will also require funding and/or in-kind institutional support for study development, equipment access, participant recruitment, and data acquisition and analysis. A successful collaboration could establish a rigorous and transferable methodology while creating a foundation for joint funding, larger-sample testing, multi-site validation, and eventual implementation across healthcare, housing, education, community, and other everyday environments.

RESEARCH TRAJECTORY

CURRENT — Question + TiD Framework + Planned Protocol → **NEXT** — Scientific Partner + Pilot Funding + Protocol Refinement + Ethics → **PILOT** — Immersive Environments + Synchronized Multimodal Data Collection → **FUTURE** — Larger Sample + Multi-Site + Real-World Validation → **GOAL** — Evidence-informed Evaluation Before Construction

8 SELECTED REFERENCES & RESOURCES

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