Ordinary Days: Context-Aware Multimodal AI for Personalized Stress Intervention

Selah Key
University of Washington
Seattle, WA, USA
selahkey@uw.edu

ABSTRACT

Chronic Autonomic Nervous System (ANS) dysregulation, triggered by long-term stress exposure, manifests in various physiological, cognitive, and behavioral symptoms. For clinically vulnerable populations like C-PTSD survivors, these symptoms are often internalized as personal failings rather than recognized as a nervous system condition because no accessible framework exists to connect their lived experience to its physiological root. While wearable technology has evolved to sense complex biometric data, a critical gap remains in translating these signals into personalized, human-centered interventions that bridge this internal disconnect.

To bridge this gap, we propose "Ordinary Days," a personalized AI-driven Digital Health Intervention (DHI) that enables real-time ANS state detection and delivers somatic practices at the moment of dysregulation. The system operates through three key components. First, it identifies unique stress reaction patterns through the 4F (Fight, Flight, Freeze, Fawn) framework to translate complex ANS states into explainable, actionable categories. Second, it triangulates real-time biometric data, voice journaling, and digital phenotyping to classify dysregulated states with user context. Third, the system non-decisively intervenes within the cognitive-emotional loop using trauma-informed language and low-friction interaction options. This approach preserves user agency while facilitating somatic relief and interoceptive awareness.

By surfacing this invisible layer of physiological experience, Ordinary Days empowers users to regulate their own nervous system, shifting mental healthcare toward proactive, personalized prevention and long-term autonomic resilience.

CCS CONCEPTS

• Applied computing → Health informatics • Human-centered computing → Ubiquitous and mobile computing • Human-centered computing → User interface design

KEYWORDS

Autonomic Nervous System, Wearable Health Technology, Digital Health Intervention, Trauma-Informed Design, Just-in-Time Adaptive Intervention, N-of-1 Personalization, Somatic Intervention, Cognitive Personal Informatics

ACM Reference format:

Selah Key. 2026. Ordinary Days: Context-Aware Multimodal AI for Personalized Stress Intervention. In *Proceedings of the 2026 CHI Conference on Human Factors in Computing Systems (CHI '26), April 13-17, 2026, Barcelona, Spain. ACM, New York, NY, USA, 4 pages.*

1. Introduction

1.1 Clinical Urgency of ANS Dysregulation

Autonomic Nervous System (ANS) dysregulation is a physiological "injury" etched into neural circuitry rather than a purely psychological phenomenon. While approximately 10.6 million U.S. adults are clinically diagnosed with C-PTSD, community prevalence is estimated at 8.59%, suggesting over 23 million Americans live in chronic dysregulation without proper classification [1]. This clinical gap is exacerbated by a median 11-year delay in diagnosis, during which untreated dysregulation increases the risk of cardiovascular and autoimmune disorders by over 50%.

Despite its prevalence, standard Cognitive Behavioral Therapy (CBT) fails 30% to 50% of C-PTSD patients during the critical Stage 1 stabilization phase [2]. This is due to a fundamental "level mismatch": chronic trauma often compromises prefrontal cortex (PFC) function, rendering cognitively demanding tasks inaccessible during acute dysregulation. In contrast, bottom-up somatic interventions that bypass cognitive deficits have demonstrated superior outcomes. For instance, Somatic Experiencing has shown significant effect sizes ($\delta = 0.94–1.26$) for symptom reduction [3], and HRV Biofeedback has produced a 24.3% reduction in PTSD symptoms ($\delta = -1.89$) within just six weeks [4].

1.2 Limitations of Existing Personal Informatics

Existing wellness applications often rely on a user-initiated model, requiring individuals to engage with content precisely when dysregulation has already compromised their executive capacity. Furthermore, while sophisticated biometric solutions exist, they often demand obtrusive hardware unsuitable for daily life. A deeper problem persists in that existing tools excel at logging *what* is happening physiologically but offer no framework for understanding *why*. For populations with limited somatic self-awareness, raw data without context feels alienating rather than empowering.

1.3 Research Contributions

To address these gaps, we present Ordinary Days, a personalized AI-driven Digital Health Intervention (DHI). This work makes the following contributions to Human-Computer Interaction (HCI) and Cognitive Personal Informatics:

- **Somatic-to-Semantic Mapping**: Application of the 4F (Fight, Flight, Freeze, Fawn) framework to translate raw biometric deviations into relatable, actionable categories.
- **Agency-Preserving Interaction Design**: Implementation of a non-decisive interaction model using trauma-informed language and low-friction response options to preserve user agency.
- **N-of-1 Personalization Paradigm**: Adoption of an N-of-1 AI model to establish individualized physiological baselines, aligning with clinical evidence that personalized stress management produces significantly stronger outcomes (p=0.049) [4].

2. System

Ordinary Days operates through a closed-loop architecture of three mutually reinforcing stages: Visibility, Understanding, and Intervention. Rather than processing data in a single pipeline, each stage continuously informs the others, creating an evolving model of the individual's unique neural signature. Figure 1 provides an overview of this architecture.

2.1 Physiological Baseline and Visibility

Ordinary Days operates on a mobile app and consumer wearable architecture, leveraging widely used devices such as Apple Watch or Oura Ring to minimize hardware friction. Upon onboarding, the system connects to existing wearable APIs to retrieve historical biometric data, including HRV (RMSSD), heart rate, skin temperature, and sleep patterns, establishing each individual's typical physiological pattern as their personal baseline. Current ANS state is then evaluated through an Allostatic Load Index, computed as sustained deviation from this norm across multiple signals over time. This stage makes otherwise invisible chronic dysregulation visible to the user, providing the foundation for downstream classification and intervention.

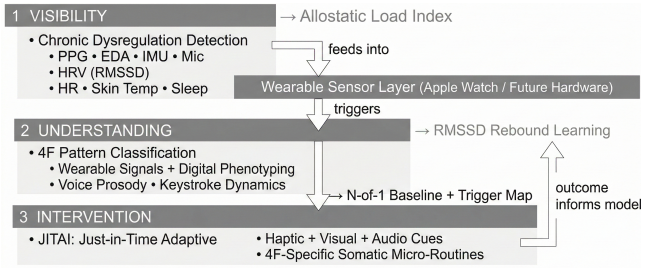

Figure 1: System architecture of Ordinary Days, illustrating the three-stage closed-loop pipeline from physiological sensing to personalized somatic intervention.

2.2 4F Detection Framework

Fight, Flight, Freeze, and Fawn (4F) originates from Polyvagal Theory and trauma-informed clinical practice, describing the four primary survival responses of the autonomic nervous system under perceived threat [5, 6]. A critical advantage of this framework is its neuro-educational utility: each 4F state maps directly onto the physical, cognitive, and behavioral symptoms that individuals already recognize in themselves, yet rarely connect to an underlying ANS condition. By grounding detection in a framework that mirrors lived experience, Ordinary Days transforms abstract biometric data into a language users can recognize and relate to, bridging the gap between physiological signals and personal understanding.

Classifying 4F states from biometric signals alone is inherently ambiguous. Fight and Flight responses share similar elevations in heart rate and EDA, yet require fundamentally different somatic interventions. The Freeze state presents greater challenge, producing a paradoxical signal of physical stillness alongside elevated EDA, a pattern easily misread as rest. To resolve this ambiguity, Ordinary Days triangulates biometric signals with behavioral and digital phenotyping markers, including voice prosody, keystroke dynamics, and notification response latency, which provide the contextual layer necessary to disambiguate overlapping physiological signals.

State	Key Detection Logic	Physiological signals	Behavioral & Digital Markers
Fight (Hyper-arousal)	High arousal and aggressive interaction: elevated HR and EDA co-occurring with hostile digital behavior	Significant HRV (RMSSD) decline; HR spike with delayed recovery; EDA phasic surge; elevated skin temperature	Aggressive typing pattern; increased vocal loudness; confrontational language in journaling
Flight (Avoi-dance)	High arousal + high mobility: elevated HR with sustained movement, accompanied by attention fragmentation	Shallow rapid breathing; unstable HRV; peripheral vasoconstriction	Accelerometer: repetitive fidgeting or purposeless movement; frequent app-switching; doomscrolling spike; notification avoidance
Freeze (Shut-down)	Immobility + hidden storm: body appears at rest while EDA signals active threat	Paradoxical signal: near-zero accelerometer alongside elevated EDA; fear bradycardia; breath-holding intervals	Screen active but zero interaction; extreme notification response latency; prolonged isolation
Fawn (Appease-ment)	Behavioral-physiological incongruence: agreeable vocal tone co-occurring with HRV stress signals	Elevated vocal pitch, excessive softness, voice jitter; baseline HRV stress pattern despite social engagement	Excessively agreeable language; compulsive immediate replies; self-neglecting behavioral patterns

Table 1: 4F Stress Response Detection Matrix, mapping physiological signals and behavioral markers to their corresponding stress response states and detection logic.

3. Human-Centered Engagement and Intervention

3.1 Intervention Timing: The Cognitive-Emotional Loop

Ordinary Days intervenes at a specific and critical point within the cognitive-emotional loop: Event → Body Signal → Emotion/Thinking → Action/Choice. For individuals with chronic ANS dysregulation, this loop is particularly vulnerable to disruption. Some users experience body signals such as throat tightness or chest discomfort without conscious cognitive awareness, while others experience emotional reactions without recognizing the underlying physiological trigger.

Consider a common scenario: An uncomfortable message arrives, producing a subtle chest constriction. Without somatic awareness, this signal bypasses conscious processing and manifests as distraction or an urge to disengage. The individual makes an impulsive choice, disrupts an ongoing routine, and later attributes the behavior to "personal weakness" rather than a regulated nervous system response. Ordinary Days intervenes before this Action/Choice stage, creating a moment of somatic awareness that interrupts the cycle of self-blame.

3.2 Trauma-Informed AI Engagement

Rather than issuing authoritative assessments, the system employs a non-decisive engagement model rooted in trauma-informed principles. When the N-of-1 model detects deviations beyond an individual threshold, the system delivers a gentle haptic cue accompanied by a simple, curious prompt: "Are you feeling okay?" This approach is intentional for three reasons:

1. **Iterative Refinement**: User feedback is essential for refining the N-of-1 TinyML model over time.
2. **Psychological Safety**: An open, curious prompt is significantly more likely to elicit engagement than a directive stress score [7], which may feel alienating or increase distress in already dysregulated users.
3. **Contextual Grounding**: A check-in framing naturally transitions into Somatic-to-Semantic mapping, connecting physiological signals to lived experience.

3.3 Low-Friction Context Collection

To minimize cognitive burden, the system presents a personalized multiple-choice prompt drawn from the user's own self-reported symptom vocabulary. Rather than generic clinical options, these choices feel personally resonant, allowing for "contextual sensemaking" even during states of diminished cognitive capacity. For users with greater availability, higher-bandwidth channels like voice memos are offered, closing the loop between physiological detection and personalized intervention.

4. Discussion

4.1 Ethical Considerations

Designing AI systems that intervene in mental health contexts raises significant ethical responsibilities. The most critical risk is what we term "algorithmic gaslighting": when the system's physiological classification contradicts the user's subjective experience, potentially eroding the very self-trust it aims to rebuild. For populations with low somatic self-awareness, an incorrect AI label may be accepted over genuine bodily signals, reinforcing distorted self-perception rather than interoceptive awareness. This is why the non-decisive engagement model described in Section 3.2 is not merely a design preference but an ethical necessity.

Privacy is equally foundational. CPI data is uniquely intimate, capturing not where a person went or what they bought, but how their nervous system responded to the world. Ordinary Days addresses this through on-device processing via TinyML and federated learning, ensuring that raw physiological and behavioral data never leaves the user's device. However, the broader question of neuro-rights, including who owns this data, who can access it, and how it may be used, remains an open challenge for the field that technical solutions alone cannot resolve.

4.2 Limitations

Several limitations of the current system design warrant acknowledgment. First, the N-of-1 baseline may itself reflect a persistently dysregulated state for populations with chronic ANS dysregulation, making it difficult to distinguish meaningful deviation from an already compromised norm. Second, the 4F classification framework, while clinically grounded, has not yet been validated against gold-standard clinical assessment in a real-world deployment. Third, the effectiveness of trauma-informed language prompts and low-friction interaction design has not been empirically tested with the target population. These limitations point directly toward the next phase of development: a participatory design study and pilot deployment with C-PTSD survivors conducted in collaboration with clinical partners.

4.3 Open Questions for the CPI Community

Ordinary Days sits at the intersection of several unresolved challenges in Cognitive Personal Informatics that we invite the community to address collectively. When is it ethical for an AI system to initiate contact during a detected dysregulated state, and who defines the threshold? How do we design context collection interactions that gather meaningful data without increasing cognitive or emotional burden on already dysregulated users? And perhaps most fundamentally: how do we build long-term trust between a user and an AI health system, particularly when that system will inevitably make errors in its earliest iterations?

5. Conclusion

Ordinary Days proposes a shift in how wearable health technology engages with its most vulnerable users: not as a passive tracker that surfaces numbers, but as a compassionate partner that meets people

at the physiological layer before impulsive choices take hold. By combining N-of-1 personalization, the 4F neuro-educational framework, and a non-decisive trauma-informed interaction model, the system offers a new path toward somatic self-awareness and long-term autonomic resilience. We invite the HCI community to a broader conversation about what it means to design technology that does not merely quantify the self but genuinely supports its healing.

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