

# Therapeutic Applications of Remote Aviation (T.A.R.A.): A Neuroergonomic Framework for Aerially Mediated Cognitive-Affective Modulation

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## ABSTRACT

Recent advances in Neuroergonomics, Affective Computing, and Remote Aviation have begun to reveal how technologically mediated sensorimotor engagement can reshape cognitive–affective regulation. Building on these convergences, this paper introduces T.A.R.A. (Therapeutic Applications of Remote Aviation) as a neuroergonomic therapeutic framework that reconceptualizes small unmanned aerial systems (sUAS) into interfaces for cognitive–emotional modulation. While prior work has primarily examined drone operation in the context of performance optimization, comparatively little attention has been given to their therapeutic potential, particularly their capacity to facilitate emotional reframing through visuospatial control. T.A.R.A. is a multi-layered system architecture that establishes an adaptive cognitive–emotional environment in which drones serve as “distance-regulated surrogates,” enabling the externalization of emotional state. A central feature of the system is the Aerial Biofeedback Loop, which infers autonomic and cognitive states through physiological indices such as lightweight EEG signals, and dynamically modulates flight parameters to guide users toward psychophysiological coherence. Rather than directly intervening at the level of the operator, T.A.R.A. achieves regulation indirectly by shaping the interaction environment itself. As such, T.A.R.A. positions itself not as a discrete intervention, but as a novel, testable paradigm that enables therapeutic transformation through the repurposing of Human machine interactions.

**Keywords:** Neuroergonomics, Therapeutic applications, Mental health, Small unmanned aerial systems (sUAS), Aerial biofeedback

## INTRODUCTION

Advances at the intersection of neuroergonomics, affective computing, and human–machine interaction are increasingly challenging traditional assumptions about how cognition, emotion, and behavior are regulated within technologically mediated environments. Emerging evidence suggests that regulation is not solely an internal, cognitively driven process, but is co-constructed through dynamic interactions between the participant and responsive systems. Despite this progress, most applications of these technologies remain oriented toward performance, efficiency, and task optimization, rather than toward therapeutic transformation.

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Conventional therapeutic models remain predominantly verbal, static, and clinic-bound, relying on reflective dialogue, cognitive restructuring, and controlled exposure within highly constrained environments. While effective across many contexts, these approaches often lack embodied, interactive regulatory environments that engage sensorimotor processes in real time. This limitation is particularly pronounced among individuals who struggle with sustained verbal processing, abstract reasoning, or emotional articulation, for whom regulation may be more effectively accessed through action, perception, and adaptive interaction rather than introspection alone.

In parallel, research in human-machine interaction (HMI) has made significant strides in optimizing performance in small unmanned aerial systems (sUAS). However, this body of work remains largely performance-oriented, prioritizing workload reduction and situational awareness, while the potential for interactive drone systems to function as therapeutic media for cognitive-emotional regulation remains largely unexplored. Drone operation entails continuous perception-action coupling, integrating visuospatial processing and fine motor control with real-time environmental feedback. Crucially, the capacity to dynamically modulate these parameters gives rise to an augmented vantage space, one that users can engage with in an embodied, externally mediated manner.

## **SCIENTIFIC FOUNDATIONS**

T.A.R.A. (Therapeutic Applications of Remote Aviation) is an interdisciplinary framework grounded in neuroergonomics, affective computing, somatic psychotherapy, exposure and narrative therapies, and positive psychology. Rather than drawing from these domains independently, it synthesizes their core principles into a unified adaptive model for cognitive-emotional regulation. Within this framework, small unmanned aerial systems (sUAS) are reconceptualized as interactive environments that can be systematized to support embodied regulatory processes.

### **Neuroergonomics and Externalized Cognitive Regulation**

Neuroergonomics examines the dynamic relationship between brain function and behavior in real-world environments, with particular emphasis on how cognitive processes can be measured and modulated using neurophysiological signals (Parasuraman & Rizzo, 2007; Ayaz et al., 2012). Advances in portable, lightweight EEG systems have enabled real-time inference of cognitive states, demonstrating the sensitivity of neural activity to task demands, environmental complexity, and sensorimotor interaction (Makeig et al., 2009; Baldwin & Penaranda, 2012). Within this perspective, cognition is not treated as an isolated internal process but as a function continuously shaped through interaction with environments. Regulation, accordingly, can be interpreted as an emergent property of brain-environment coupling, in which attentional dynamics and cognitive load are distributed across task structure and interface design instead of governed solely by internal, deliberate control.

However, the application of neuroergonomic principles has largely remained confined to performance optimization domains. T.A.R.A. elaborates on this paradigm by repositioning neuroergonomics within a therapeutic context. Through NeuroAerial Engagement (NAE), drone-based interaction tasks are designed to modulate attentional focus, facilitate flow states, and stabilize cognitive variability via continuous sensorimotor coupling. Simultaneously, the Aerial Biofeedback Loop (ABL) leverages neurophysiological inference to dynamically adjust task difficulty and environmental parameters in real time. In lieu of instructing users to regulate internally or relying on explicit cognitive strategies, T.A.R.A. externalizes regulation by embedding it within the interaction environment itself. In doing so, cognitive–emotional stabilization is derived from adaptive task–environment coupling, allowing regulation to be enacted through engagement and interaction over introspection alone.

### **Affective Computing and Adaptive Biofeedback Systems**

Building upon neuroergonomic principles of brain–environment coupling, affective computing focuses on the detection, interpretation, and adaptive response to human emotional and physiological states, permitting systems to recognize affective behavioral signals and respond accordingly in real time. Contemporary approaches leverage multimodal physiological inputs such as heart rate variability (HRV), galvanic skin response (GSR), and EEG to infer emotional arousal, cognitive load, and engagement with increasing accuracy (Fairclough, 2009; D’Mello & Kory, 2015). These developments have given rise to closed-loop biofeedback systems in which continuously monitored user states are used to inform system responses.

Traditionally, affective computing has relied on feedback-centric designs in which users are made explicitly aware of their internal states and guided toward regulation through visualizations, prompts, and designed training protocols (Picard, 1997; Peper et al., 2009). While such approaches have demonstrated effectiveness in domains such as stress regulation, emotional awareness, and biofeedback-assisted therapy, they depend heavily on conscious interpretation and deliberate self-regulation. This places additional cognitive demands on the user and assumes a level of introspective access that may not always be available or reliably actionable.

In contrast, T.A.R.A. further refines affective computing into a neuroergonomic, environment-mediated framework of regulation. Through the Aerial Biofeedback Loop (ABL) and the broader TARA-AI adaptive system, physiological signals are not presented directly to the participant but are instead used to modulate the interaction environment itself. Flight parameters such as speed, maneuver complexity, and horizon stability are dynamically adjusted in response to inferred cognitive–emotional states, subtly guiding the participant toward psychophysiological coherence. In this formulation, regulation is embedded within the perception–action loop, allowing stabilization to arise implicitly through curated interaction. By shifting from feedback-driven awareness to environment-driven modulation, T.A.R.A. reduces reliance on conscious control, enabling a more intuitive, experience-based pathway to cognitive–emotional regulation.

## **Somatic Psychotherapy and Embodied Regulation**

Expanding on Affective Computing, Somatic Psychotherapy foregrounds the body as a primary site of emotional processing and regulation (Ogden et al., 2006). Within this school of thought, cognitive and affective states are perceived as deeply embedded in sensorimotor experience, such that changes in movement, posture, and physiological arousal can directly influence emotional states (Payne et al., 2015; Levine, 2010). This perspective challenges purely cognitive models of therapy by proposing that regulation cannot be achieved solely through verbal reflection but must also engage the continuous interplay between physiological states and bodily movement. Accordingly, somatic approaches emphasize grounding, interoceptive awareness, and autonomic modulation through practices such as breath regulation and controlled motor engagement, which have been shown to support emotional stabilization (van der Kolk, 2014).

While somatic interventions have validated clinical efficacy, their application is often constrained by the absence of scalable ecosystems capable of consistently scaffolding embodied regulation. T.A.R.A. addresses this systematic limitation by extending somatic principles into a technologically mediated, neuroergonomic context, embedding sensorimotor engagement directly within drone operation. Through continuous interaction with the control interface, users engage in fine-grained motor regulation and visuospatial tracking, intrinsically linking sensorimotor activity with attentional and emotional states. As a result, emotional regulation is propagated through synchronized perception–action dynamics within the interaction itself. In NeuroAerial Engagement (NAE), elements such as control smoothness, rhythmic micro-adjustments, and sustained motor engagement function as implicit regulatory mechanisms that shape both cognitive stability and affective state.

As opposed to isolating the body as a discrete therapeutic target, T.A.R.A. reframes somatic regulation as a distributed process across a closed interaction loop, in which internal physiological states are continuously modulated through reciprocal coupling with the external environment. In doing so, emotional stabilization is achieved through coordinated engagement with a responsive environment rather than through internally directed bodily awareness alone.

## **Exposure and Narrative-Based Therapeutic Processes**

Within the broader framework of environment-mediated regulation, exposure-based therapies demonstrate that gradual engagement with anxiety-inducing and challenging stimuli can facilitate desensitization and increase tolerance for uncertainty (Foa & Kozak, 1986; Craske et al., 2014). By systematically varying exposure intensity, individuals develop resilient coping strategies to regulate physiological and emotional responses while maintaining optimal function. Complementing this, narrative therapy accentuates the reinterpretation of lived experience through systematized meaning-making, empowering individuals to reconstruct personal narratives in ways that support psychological growth (White & Epston, 1990).

Although both approaches are empirically established, they are typically implemented in discrete, therapist-guided contexts that separate experiential engagement from reflective processing. T.A.R.A. integrates these mechanisms within a unified interaction architecture composed of these two complementary subsystems. Therapeutic Mission Design (TMD) further operationalizes graded exposure through drone flight tasks that incrementally modulate complexity and uncertainty, allowing users to engage with calibrated stressors while remaining cognizant of their current cognitive–emotional bounds.

Simultaneously, Aerial Narrative Therapy (ANT) leverages recorded flight experiences and shifts in perspective to facilitate narrative reframing and salience weighting of experience. Through deliberate journaling, guided reflection, and media-based reconstruction, participants reimagine their actions, decisions, and emotional responses within a coherent experiential network. By embedding both exposure and narrative components, T.A.R.A. supports a continuous progression toward cognitive insight through an iterative cycle of engagement, interpretation, and transformation.

### **Positive Psychology and Growth-Oriented Development**

Shifting the focus from stabilization to sustained development, positive psychology emphasizes the cultivation of strengths, resilience, and well-being through constructs such as flow states and self-efficacy (Seligman & Csikszentmihalyi, 2000). Flow states, in particular, are characterized by deep engagement and intrinsic motivation that emerge when task demands are optimally matched to an individual's skill level (Csikszentmihalyi, 1990). Consequently, they are marked by heightened focus, reduced self-referential thinking, and an increased sense of control, all of which contribute to enhanced psychological well-being. Moreover, repeated engagement in flow-conducive activities strengthens self-efficacy and supports long-term adaptive behavior. Within this school of thought, psychological health is not defined solely by the reduction of distress, but by the capacity to engage meaningfully with challenges, develop competence, and construct a sense of purpose (Bandura, 1997). Accordingly, regulation and growth are best understood as interdependent processes, not separate outcomes.

T.A.R.A. incorporates these principles through Compassionate Operator Development (COD), which frames the participant not merely as a passive recipient of intervention, but as an evolving agent on a trajectory of growth. Successful navigation of drone-based tasks is likely to result in participants encountering challenges that promote mastery, adaptive persistence, and self-directed progression contributing to enhanced attentional control, emotional resilience, and confidence. By embedding opportunities for flow states, competence-building, and meaning-making within the interaction environment itself, T.A.R.A. develops beyond immediate regulation toward deeper processes of self-awareness, emotional insight, and consolidated identity formation. This interaction loop not only supports the reduction of stress and dysregulation but also promotes the cultivation of a coherent sense of agency and sustained psychological well-being.

## **Toward Environment-Mediated Therapeutic Regulation**

Taken together, these scientific foundations converge on a central premise: cognitive–emotional regulation can be actively shaped through purposeful interaction with the external environment. Neuroergonomics provides the basis for measuring and modulating cognitive states, affective computing permits closed-loop system responsiveness, somatic psychotherapy situates regulation within embodied engagement, and exposure and narrative therapies introduce mechanisms for transformation and meaning-making. Positive psychology, in turn, frames these processes within a broader trajectory of growth and well-being. T.A.R.A. synthesizes these domains into a cohesive system that embeds therapeutic mechanisms directly within the fabric of human–machine interaction. In this formulation, the interaction is no longer ancillary to intervention but constitutes the vehicle through which the intervention is carried out. Building on this reconceptualization, T.A.R.A. establishes a foundation for a new class of neuroergonomic systems that reframe drones from operational instruments into state-sensitive neurotherapeutic interfaces, where flying serves as the primary channel through which cognitive–emotional revitalization is realized.

Developing upon this framework, the contribution of this work is threefold. First, it presents a multi-layer neurotherapeutic aviation architecture that augments traditional therapeutic practices with neuroergonomics and modern affective computing. Second, it extends therapeutic design beyond a purely conceptual model by outlining an operational ecosystem comprising adaptive biofeedback, mission design, narrative integration, and developmental scaffolding. Third, it advances a novel perspective on therapeutic intervention, proposing regulation achieved indirectly through the manipulation of surrounding environments rather than through direct instruction. By positioning drones as interactive, sensorimotor therapeutic systems, this framework addresses a gap in both therapeutic practice and HMI research. It introduces a new class of intervention in which the mechanism of change proliferated by the dynamics HMI itself. In doing so, T.A.R.A. establishes a foundation for future empirical investigation into how such concepts can be leveraged to support future therapeutic cognitive–emotional modulation.

## **THE FIVE-PILLAR NEURO-THERAPEUTIC AVIATION MODEL**

The T.A.R.A. framework operationalizes its principles through a five-pillar neuro-therapeutic aviation model. Each pillar represents a distinct functional layer within the system, collectively structuring how interaction, adaptation, and reflection are coordinated to produce cognitive–emotional regulation. Rather than acting as independent components, these pillars operate as an integrated architecture in which engagement, adaptation, challenge, meaning-making, and development are continuously co-regulated through the interaction environment.

### **NeuroAerial Engagement (NAE)**

NeuroAerial Engagement (NAE) establishes the primary interaction layer through which participants engage with the system. It centers on continuous

drone flight as an attentional anchor, requiring sustained visuospatial tracking and fine motor coordination. Task conditions are organized to promote stable engagement by balancing precision, responsiveness, and perceptual flow, empowering users to remain actively aligned with the environment. Rather than directing attention internally, NAE facilitates regulation through externally guided interaction, where stability of engagement becomes the primary driving force of the experience. Within the broader system, NAE functions as the entry point through which all subsequent adaptive and developmental processes are initiated.

### **Aerial Biofeedback Loop (ABL)**

The Aerial Biofeedback Loop (ABL) functions as the adaptive control layer of the system, continuously modulating interaction conditions in response to inferred user states. Physiological and behavioral signals are used to dynamically adjust parameters such as flight sensitivity, maneuver complexity, and environmental stability. These adjustments occur in real time, without requiring explicit user awareness, allowing the interaction environment to remain seamlessly aligned with the participant's current cognitive capacity. By maintaining an optimal range of challenge and stability, ABL ensures that engagement remains neither overwhelming nor under-stimulating. As such, it serves as the regulatory backbone of the system, continuously shaping the interaction space in which cognitive–emotional processes unfold.

### **Therapeutic Mission Design (TMD)**

Therapeutic Mission Design (TMD) structures the progression of interaction through purpose-driven flight tasks that vary in complexity and demand. Missions are designed to introduce controlled variability, requiring users to navigate changes in speed, spatial orientation, and decision-making under shifting conditions. This layer governs how challenge is introduced, sequenced, and scaled across sessions, ensuring that participants encounter manageable levels of uncertainty and difficulty. Instead of exposing users to static conditions, TMD creates a dynamic progression in which each task builds upon prior interaction states. Within the system, it functions as the mechanism through which challenge is calibrated and development is systematically advanced.

### **Aerial Narrative Therapy (ANT)**

Aerial Narrative Therapy (ANT) provides the reflective layer through which interaction experiences are interpreted and integrated. Flight data, visual recordings, and task outcomes are used to reconstruct sequences of action, allowing participants to revisit and reinterpret their responses within the interaction environment. This process supports the organization of experience into coherent narratives, linking perception, action, and outcome into a coordinated understanding of engagement. Rather than separating reflection from interaction, ANT anchors meaning-making in lived experience, allowing participants to derive insight from their own patterns of behavior. Within

the system, it serves as the bridge between interaction and interpretation, transforming engagement into personal understanding.

### **Compassionate Operator Development (COD)**

Compassionate Operator Development (COD) represents the developmental layer of the system, extending beyond immediate interaction toward longer-term growth and self-perception. It frames the participant as an evolving agent, emphasizing progression, adaptability, and self-directed improvement across repeated engagements. Performance within the system is contextualized not as success or failure, but as part of an ongoing developmental journey, reinforcing continuity across sessions. Through this lens, interaction becomes a vehicle for cultivating consistency, resilience, and self-awareness over time. COD thus functions as the integrative layer that consolidates repeated interaction experiences into a coherent sense of capability and agency.

### **Framework Synthesis of the Five Pillars**

Together, these five pillars form an integrated system in which engagement, adaptation, challenge, reflection, and development are continuously coordinated. NeuroAerial Engagement anchors the interaction, the Aerial Biofeedback Loop maintains adaptive alignment, Therapeutic Mission Design structures progression, Aerial Narrative Therapy enables interpretation, and Compassionate Operator Development consolidates long-term growth. These components function in a sequential closed-loop architecture, where each layer informs and reinforces the next. Through this amalgamation, T.A.R.A. establishes a responsive interaction environment in which cognitive–emotional regulation is achieved through the dynamics of the system itself.

## **APPLICATIONS AND PROGRAM FORMATS**

The T.A.R.A. framework is designed as a flexible, scalable system that can be adapted across diverse contexts while maintaining its core principle of environment-mediated cognitive–emotional regulation. Its modular architecture enables deployment across educational, clinical, professional, and rehabilitative fields, with each application tailoring interaction parameters, mission design, and developmental focus to the needs of specific populations.

### **TARA-Lite: Educational and Youth Contexts**

TARA-Lite is a streamlined version of the framework designed for school and adolescent settings, targeting attentional stability, emotional awareness, and safe technology use. It combines basic drone tasks with brief reflection to build self-awareness and confidence. The system adapts to diverse needs: short, high-engagement missions sustain focus in ADHD; structured, low-risk tasks gradually build autonomy in anxiety; and simplified, predictable environments support neurodiverse learners. In classrooms, collaborative missions foster communication and empathy, while guided discussions reinforce digital safety and ethics. By aligning task complexity and feedback

with development, TARA-Lite promotes regulation, engagement, and responsible human–technology interaction.

### **TARA-Clinical: Therapist-Supervised Applications**

TARA-Clinical applies the framework in therapist-supervised settings to support anxiety, stress-related disorders, and emotional dysregulation. Integrated with established therapies, it emphasizes regulation through structured interaction. Task design is clinically tailored: graded flight challenges enable safe exposure for anxiety; controlled, low-sensory environments foster safety in trauma; and real-time difficulty adjustments support stabilization in emotional dysregulation. Reflection links task performance to internal states, strengthening awareness and control. By aligning task parameters with therapeutic goals, TARA-Clinical offers an alternative pathway for clients who struggle with verbal methods, while maintaining clinical oversight and the therapeutic alliance.

### **TARA-Professional: High-Performance Operational Settings**

TARA-Professional is designed for high-performing individuals such as corporate leaders, athletes, and academics operating under sustained cognitive pressure and at risk of burnout, performance anxiety, and attentional fatigue. It focuses on optimizing regulation to support consistency, clarity, and resilience under dynamic demands. Task design is performance-specific: executives engage in decision-heavy missions under time constraints to build cognitive flexibility; athletes train precision and flow through controlled, progressive movement tasks; and academics develop endurance via sustained attention and stability exercises. Adaptive challenges simulate pressure while preventing overload. By embedding adaptive challenge and feedback within the interaction itself, T.A.R.A. supports the development of consistent performance patterns while reducing the cognitive cost of maintaining control in complex environments.

### **TARA-Rehabilitation: Recovery and Cognitive Re-engagement**

TARA-Rehabilitation supports individuals recovering from trauma and neuropsychological disruption, including PTSD, abuse-related trauma, and schizophrenia. It prioritizes restoring agency, stability, and safe re-engagement with cognitive and sensorimotor processes through structured, low-risk interaction. Tasks are carefully graded: for PTSD, low-stimulation environments and stable hover tasks minimize triggers while gradually increasing variability; for trauma survivors, predictable navigation with clear boundaries reinforces safety and control; and for schizophrenia, simplified tracking tasks support attentional grounding and reduce fragmentation. Clinician-supervised co-regulation ensures safety throughout. As such, it provides a coherent pathway for recovery that extends beyond isolated exercises, supporting the renewed sense of agency within a controlled environment.

## LIMITATIONS AND ETHICAL CONSIDERATIONS

While these applications demonstrate the flexibility and potential impact of the T.A.R.A. framework, its implementation raises important technical, ethical, and clinical considerations. As a system that integrates real-time adaptation, physiological inference, and physical interaction with drone platforms, careful attention must be given to both user safety and the responsible use of sensitive data.

### Risk of Overstimulation and Cognitive Overload

The adaptive nature of T.A.R.A., while central to its effectiveness, also introduces the risk of overstimulation if interaction parameters are not appropriately calibrated. Rapid changes in task difficulty, environmental instability, or prolonged engagement may exceed an individual's cognitive or emotional capacity, particularly in vulnerable populations. Ensuring that adaptive systems maintain appropriate bounds is therefore critical, requiring careful design of thresholds, fail-safes, and session duration guidelines.

### Safety Considerations in Drone Operation

The use of physical drone systems introduces inherent safety risks associated with navigation, environmental obstacles, and potential loss of control. These risks are particularly relevant in unsupervised or non-controlled environments. Safe implementation requires regulated operational protocols, including the use of simulation environments where appropriate, supervised deployment in early stages, and adherence to established aviation safety guidelines. The physical dimension of the system distinguishes it from purely digital interventions and necessitates corresponding safeguards.

### Data Privacy and Physiological Monitoring

The integration of physiological signals such as heart rate variability, galvanic skin response, and EEG raises important considerations regarding data privacy and user consent. These data streams can reveal sensitive information about cognitive and emotional states, requiring secure data handling, transparent usage policies, and strict adherence to ethical standards in collection, storage, and analysis. Ensuring that participants retain agency over their data is essential for maintaining trust and preventing misuse.

## CONCLUSION AND FUTURE DIRECTIONS

T.A.R.A. establishes a foundation for a new class of interaction-driven therapeutic systems, and its most significant impact lies in the directions it opens for future development. Next steps will center on rigorous empirical validation through multimodal studies integrating EEG, HRV, and behavioral analytics to quantify how adaptive flight environments influence cognitive–emotional regulation across populations and contexts. Parallel efforts will focus on advancing the TARA-AI architecture toward fully autonomous,

state-aware systems capable of personalizing task design, progression pacing, and environmental modulation in real time. This includes expanding into simulation ecosystems, remote delivery models, and cross-platform integrations that enable scalable deployment in clinical, educational, and high-performance settings. Further research will also explore adaptive protocols for neurodiverse populations, longitudinal effects on resilience and self-regulation, and integration with existing therapeutic frameworks. Ultimately, T.A.R.A. points toward a future in which therapeutic systems are no longer static or clinician-bound, but continuously evolving, responsive environments—where interaction itself becomes a programmable pathway for sustained cognitive–emotional transformation.

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