Neuroadaptive Companion System: A Passive Multi-Modal Platform for Predicting and Mitigating Dysregulation in Autism

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Executive Summary

Autism Spectrum Disorder (ASD) is a highly individualized neurodevelopmental condition characterized by challenges in social interaction, communication, and sensory processing. For many families, acute episodes of behavioral dysregulation—including meltdowns, shutdowns, or sensory overloads—can be unpredictable and distressing. This whitepaper proposes a novel, privacy-respecting, wearable system that passively monitors biometric, environmental, and neurological signals to predict these episodes and deliver non-invasive, personalized interventions.

Over time, the system builds a tailored behavioral map for each individual, enabling real-time detection of rising dysregulation risk and closed-loop, multi-sensory support. The ultimate goal is to reduce the frequency and intensity of acute episodes while enhancing autonomy and quality of life.

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1. Background and Motivation

Despite increasing awareness, autism remains poorly understood at a systems level. Pharmacological solutions are often non-specific, and behavioral therapies, while helpful, rely on human interpretation and retrospective observation. Families and educators frequently lack real-time tools to anticipate or interrupt a dysregulation event.

Emerging wearable and neuroadaptive technologies now offer a path forward. By combining passive data collection with contextual modeling and closed-loop interventions, we can build personalized systems that respond not to generalized diagnoses, but to **individual neural patterns in real-world settings**.

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2. System Overview

The Neuroadaptive Companion System (NCS) is a four-tier, modular platform:

Tier 1: Passive Monitoring

- **Devices**: Smartphone, smartwatch, ring (e.g., Oura), EEG headset (e.g., Flow Neuroscience, Elemind, Mendi)

- **Signals Collected**:

  - Heart rate, HRV, EDA (stress markers)

  - Respiration rate, skin temperature

  - Accelerometry & gyroscope (movement, restlessness)

  - Environmental audio classification (sudden noise, speech patterns)

  - App/screen usage & visual/auditory stimulus exposure

  - Location, crowd density via Bluetooth proximity

  - Optional: EEG pattern trends (focus, overload, attention drift)

Tier 2: Pattern Detection & Prediction

- Machine learning models trained on individual history

- Temporal sequence modeling (GRU, Transformer)

- Event labeling via caregiver input

- Predictive scoring of dysregulation risk in real time

Tier 3: Alerting & Human Support

- Caregiver notifications (text, vibration, app alert)

- Event marker injection for later analysis

Tier 4: Adaptive Interventions (Optional)

- Audio: calming tones, speech, white/pink noise

- Haptics: vibration cues (watch, ring)

- Visual: screen pulse or animation

- Neurostimulation: EEG-guided tACS/tDCS (via partner devices)

3. Data Security and Privacy

- **On-device encryption** (AES-256) and ephemeral data buffers

- **Consent-based upload** to HIPAA-compliant, encrypted cloud

- **No raw audio or GPS coordinates** retained – only derived context

- **User and caregiver control** of what data is stored and when

4. Pilot Study Roadmap

See accompanying IRB-safe research plan for proposed 12-month study involving 10–20 families:

- Phase 1: Passive data logging and risk model training

- Phase 2: Risk detection and caregiver alert testing

- Phase 3: Gentle intervention trials and feedback

5. Impact and Potential

The Neuroadaptive Companion System offers:

- **Early prediction of dysregulation** before it becomes overwhelming

- **Non-invasive, child-specific support** without medication

- **Data-driven tools for families, educators, and clinicians**

- A future foundation for **closed-loop therapeutic neuromodulation**

Over time, this system may evolve to support other neurodivergent conditions (e.g., ADHD, anxiety disorders), and to personalize education and behavioral supports across environments.

6. Conclusion

The intersection of biometric monitoring, ambient context sensing, and adaptive neurotechnology offers a revolutionary opportunity: to give neurodivergent individuals and their caregivers **real-time insight, personalized support, and proactive safety**. With care, consent, and community-centered design, we can build tools that empower users rather than pathologize them—tools that listen to the brain, and respond with empathy.