

ADEPT-VR: A Large Language Model Based Adaptive De-escalation Trainer for Police Training

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Executive Summary

- Traditional de-escalation training relies on role-play and lacks consistency, scalability, and measurable feedback.
- We developed **ADEPT-VR**, an adaptive training system that combines **real-time conversational AI** with **immersive virtual reality** to simulate high-risk interactions.
- A pilot study with active-duty officers showed high conversational coherence and emotional realism, with no major misunderstandings and manageable workload (**avg. latency: 4.3 s**).
- To extend evaluation, **EEG was used to measure cognitive engagement** and behavioral readiness during VR scenarios, showing increased engagement during task-critical phases.
- ADEPT-VR demonstrates a scalable and measurable approach toward immersive, data-driven de-escalation training for police officers.

Background

- De-escalation is a communication-driven approach to reduce tension and minimize use of force in high-risk situations.
- Traditional training relies on role-play and scripted scenarios, which are **resource-intensive, inconsistent, and not easily scalable**.
- These methods provide limited measurable feedback on officer performance.
- Advances in LLMs, RAG, and emotional TTS enable realistic, adaptive, and context-aware interactions.
- This work integrates AI, VR, and EEG to enable adaptive and measurable de-escalation training.

Experimental Setup and Test Plan

AI De-escalation System

- ADEPT-VR operates as a real-time closed-loop system: speech → transcription → AI response → speech.
- Speech-to-Text**: openai/whisper-large-v3(~0.5 s).
- LLM**: google/gemma-3:27B (currently testing gemma-4:26B) for coherent, context-aware dialogue.
- RAG**: Retrieves scenario-specific context to maintain grounded and consistent interactions.
- Emotional Modeling**: Virtual subject's emotional state updates dynamically based on officer input.
- Text-to-Speech**: Supertone/supertonic-2 with ongoing experiments for expressive voice generation.
- Modular design allows easy component upgrades and testing.

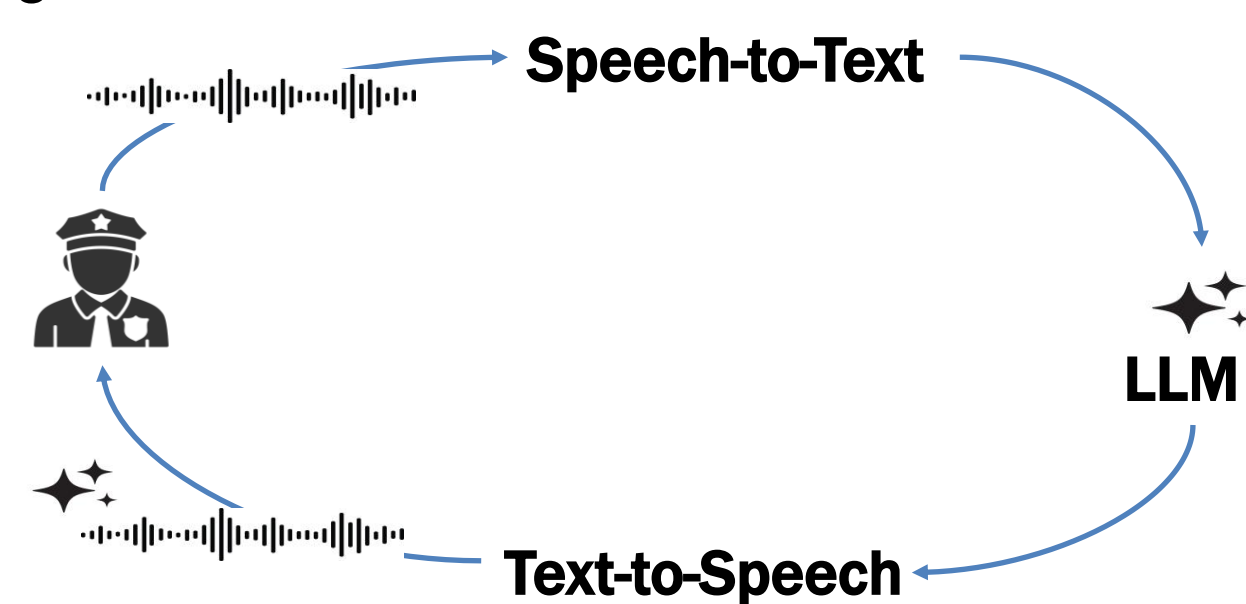


Figure 1. Low Level Architecture – Adaptive De-escalation Trainer

Experimental Setup and Test Plan

VR + EEG Integration

- The system is deployed in an immersive VR environment built in **Unity** with **full in-house development** in our lab.
- Characters (**Character Creator 4**) and animations (**Blender and Mocap**) support realistic interaction.
- Three scenarios implemented (expanding to five), including high-risk crisis situations.
- EEG (**EMOTIV EPOC X**) is used to capture cognitive engagement during the interaction.
- This setup enables adaptive, realistic training while capturing objective engagement signals in real time.



Figure 2. Pilot study measurement setup using VR (Meta Quest 3) and EMOTIV EPOC X EEG recording.

System Evaluation (w/o VR)

- Conducted with 3 active-duty police officers (~19 years average service).
- Participants engaged in real-time verbal interaction with the AI-simulated subject to attempt de-escalation.
- Focused on **evaluating conversational performance without VR immersion**.

Measures included:

- Conversational flow, coherence, and responsiveness
- Emotional realism and appropriateness of reactions
- Workload using **NASA-TLX**
- System performance (latency per turn)
- Hypotheses (1 - 4) assessed conversational quality, emotional realism, adaptive behavior, and technical feasibility

Together, these studies evaluate system performance, user perception, and cognitive engagement in de-escalation training.



Figure 3. ADEPT-VR Training Scenes: (a) Scenario selection interface; (b) officer interacting with the AI-simulated subject; (c) decision-making interface where officers can choose actions (e.g., shoot or use a taser) based on the scenario.

VR + EEG Study (Immersive Interaction)

- Conducted with a separate set of participants using the full VR system.
- Participants completed scenario-based de-escalation tasks in an immersive VR environment.
- EEG recorded brain activity to assess **cognitive engagement during interaction**.
- Engagement analyzed across different phases of the scenario (**baseline, active interaction, peak decision-making, cooldown**).
- The EEG topographic map shown represents sample data from one participant during the VR session.

Experimental Results

- High ratings for **conversational flow, consistency, and realism** (> 5.5 / 7); no major misunderstandings.
- Emotional responses felt human-like**, supporting realistic interaction.
- Moderate workload (mental: 4.3, temporal: 5.3) with low frustration (2.3).
- Average latency **4.3 s per turn**; STT and TTS were main bottlenecks.
- EEG shows **increased engagement during active and critical phases** of the scenario.
- Demonstrates **real-time, realistic interaction with measurable cognitive engagement**.

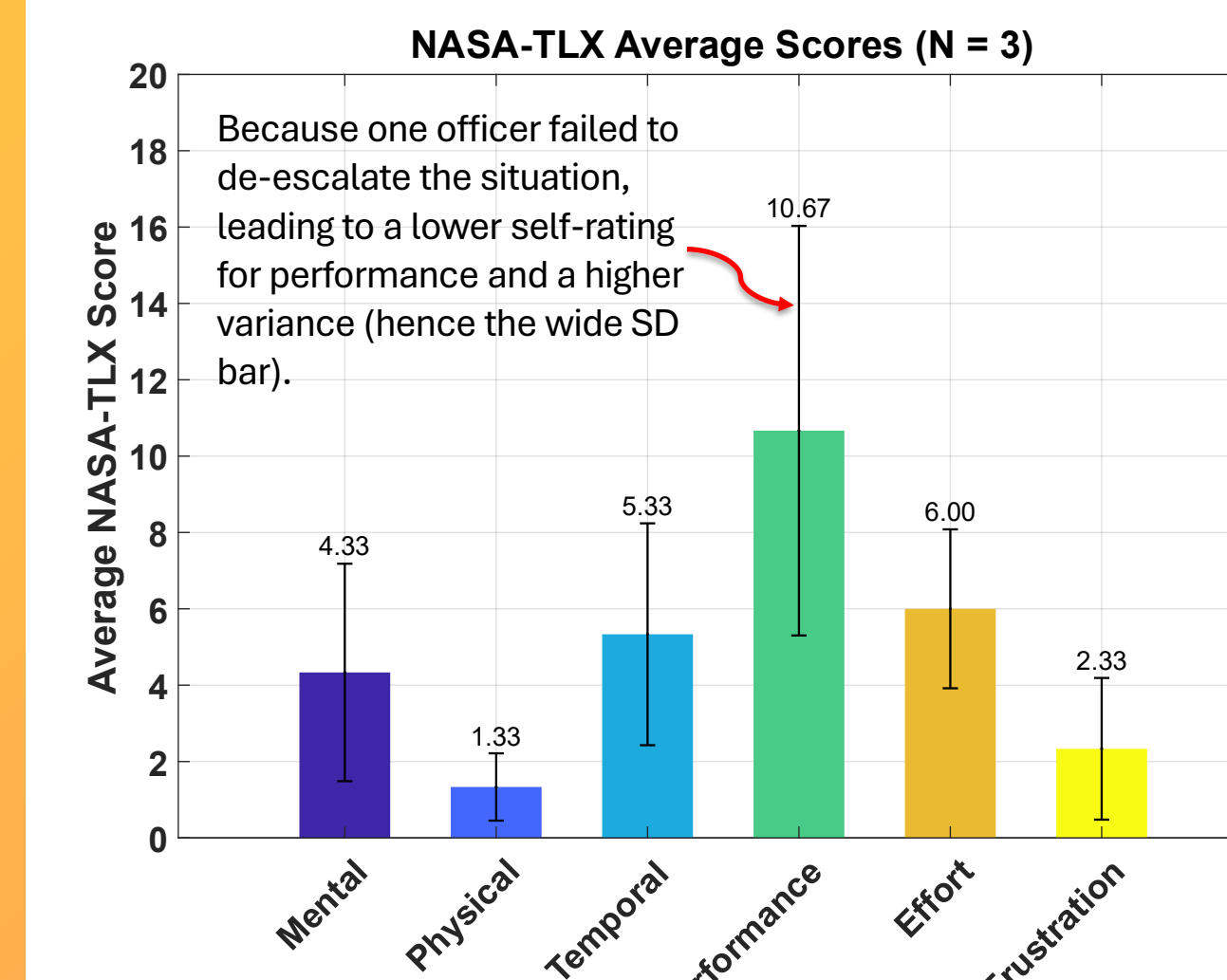


Figure 5. Average perceived workload across NASA-TLX dimensions after AI simulator use. (Lower is better)

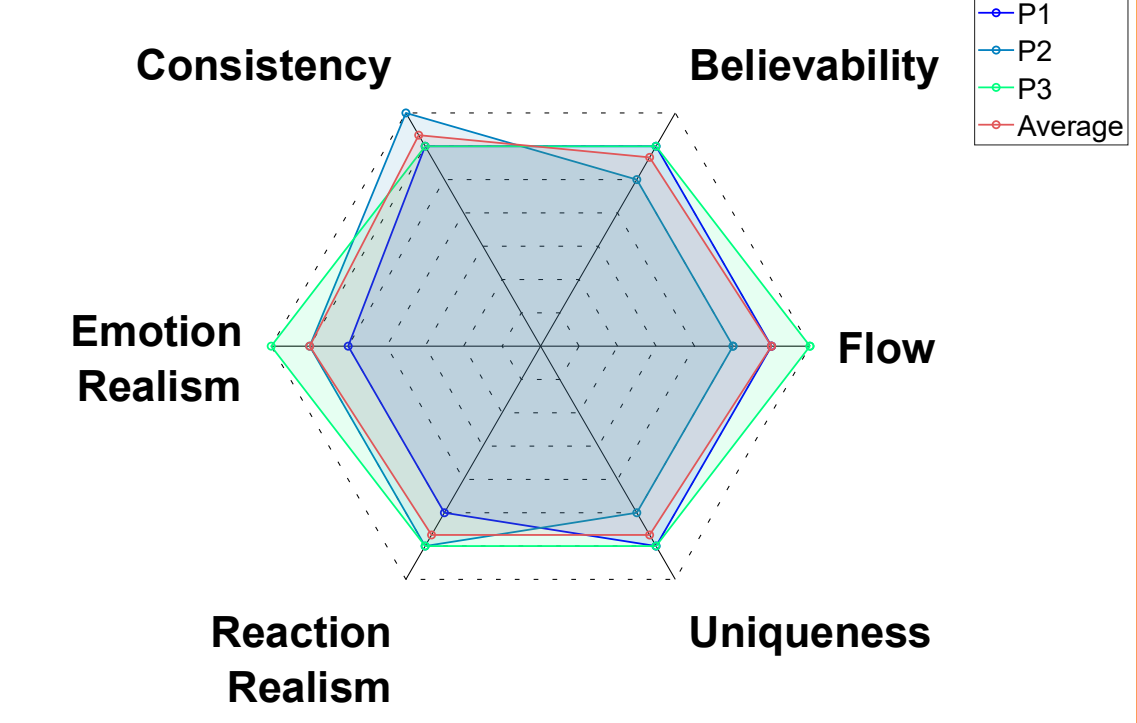


Figure 4. Officer ratings on Consistency, Believability, Flow, Uniqueness, Reaction Realism, Emotion Realism on a 7-point scale. (Higher is better)

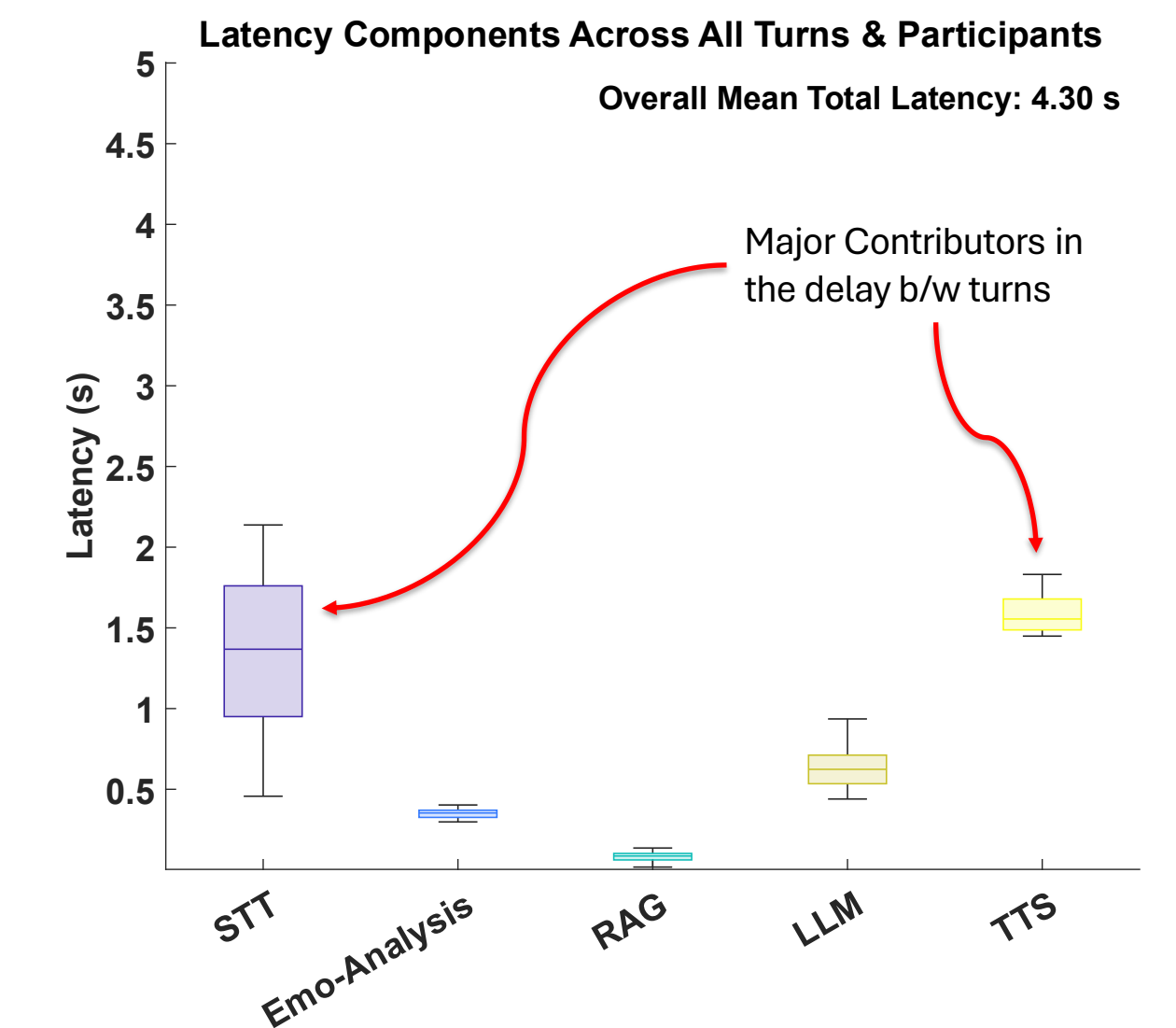


Figure 6. Latency distribution for system components (Lower is better)

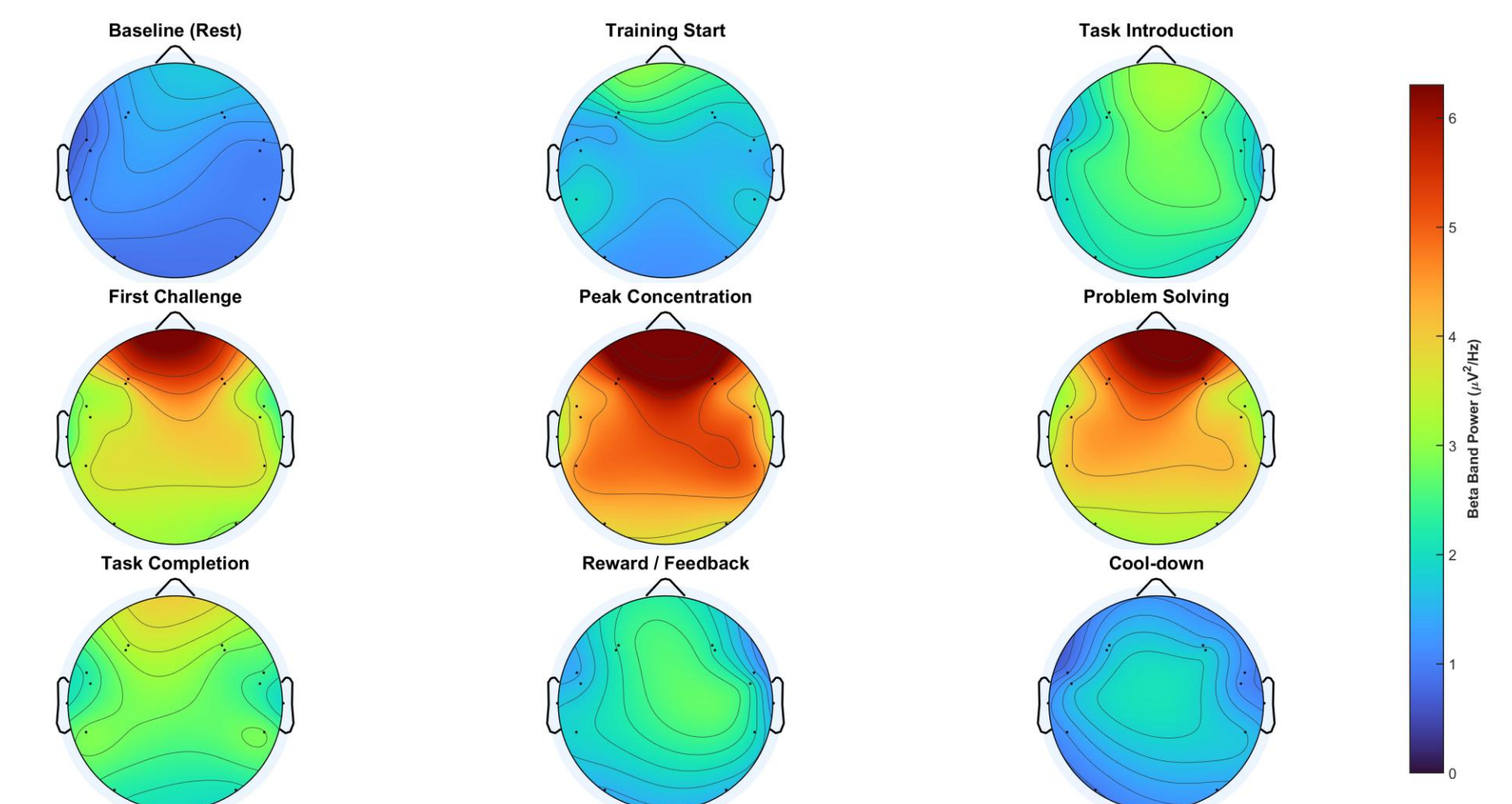


Figure 7. EEG Topographic Maps (Sample Participant): Spatial distribution of beta band power ($\mu V^2/Hz$) across task phases, with elevated activity during high cognitive demand states.

Conclusions

- ADEPT-VR enables **realistic and adaptive AI-driven de-escalation training**.
- High conversational quality with manageable workload and real-time performance.
- VR integration supports **immersive, scenario-based interaction**.
- EEG shows **measurable cognitive engagement during critical phases**.
- Modular design allows **scalability and future improvements**.

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