Teaming with AI: A Multi-Modal Investigation of Human-AI Team Dynamics

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1 Introduction

Integrating artificial intelligence (AI) into human teams is widely expected to enhance performance and collaboration. However, AI agents often lack the adaptability and capability required for seamless collaboration. This study investigates the cognitive, behavioral, and physiological dynamics in human-AI collaborations. We developed a virtual reality-based multi-agent distributed control task and collected participants' multi-modal physiological and behavioral data while performing the task with or without an embodied AI. We also include a framework that can predict future actions of team members based on others' physiological and behavioral data in human-only teams, and we showed such predictability is correlated with team performance.

2 Methods

We conducted an embodied collaborative control task to examine how human-like AI teammates influence team performance, cognitive dynamics, behavior, and physiological responses of human participants. Our experimental design leverages the Apollo Distributed Control Task (ADCT), a complex sensorimotor task in a virtual reality (VR) environment. Participants collaborated in triads, comprising either all-human teams or teams with a Wizard of Oz (WOz) AI agent, which is controlled by a human expert (Figure 1 a). We collected and analyzed multi-modal data, including team performance metrics, motor actions, verbal communication, and physiological signals (i.e., pupil size, blink rate, and electroencephalography (EEG)) [1, 2].

3 Results

3.1 Behavior Dynamics

Surprisingly, our findings challenge prevailing assumptions about the benefits of human-AI collaboration. Contrary to expectations, teams involving a WOz AI agent exhibited significantly lower performance than all-human teams. This decline was accompanied by pronounced changes in human remote controller action inputs. As shown in Figure 1 b, all-human teams outperformed human-AI teams. Even though a human expert controlled the WOz AI agent, the presence of an AI team member led to a decrease in overall team performance.

The behaviors of participants also change in human-AI teams. Figure 1 c revealed that participants working with the AI agent executed more remote controller actions than those in all-human teams, despite the agent's action frequency being similar to human counterparts. This suggests that participants felt a heightened need to assert control or compensate for perceived deficiencies when collaborating with an AI.

Effective communication is crucial for successful collaboration. Our analysis compared communication frequency and duration between human-only and human-AI teams. Findings indicate that human-AI teams communicated less frequently and for shorter durations than human-only teams (Figure 1 d), suggesting that the introduction of AI alters team communication dynamics.

3.2 Physiological Responses

Participants collaborating with the AI agent exhibited increased pupil dilation, indicating heightened arousal and cognitive load (Figure 1 e). Higher blink rates in human-AI teams further suggested reduced engagement and elevated stress levels (Figure 1 f). EEG analysis revealed greater delta and theta synchrony in human-AI teams, whereas human-only teams showed higher alpha and beta synchrony (Figure 1 g). These physiological responses suggest that human-AI teaming induces greater arousal and lower engagement, which correlates with reduced team performance.

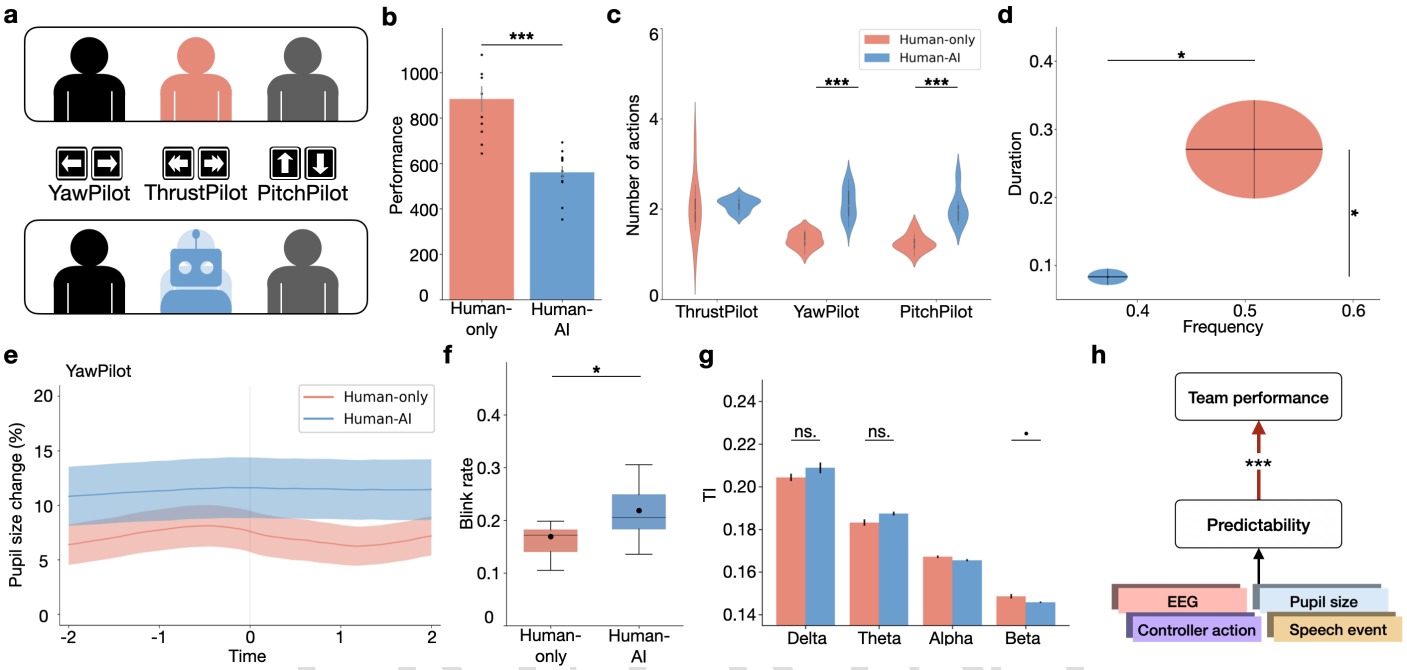

Figure 1: **a**, An illustration of human-only and human-AI team. **b**, Team performance is measured by the number of rings passed. Each dot indicates one team (N = 17). **c**, Number of remote controller actions. **d**, Communication frequency and duration among team members. **e**, Pupil size changes from baseline over time. **f**, Blink rate of participants. **g**, Inter-brain synchrony among different frequency band. **h**, Predictive modal input and correlation with team performance. Asterisks indicate statistically significant differences, defined as ns, not significant, $\cdot$ $P < 0.1$, $*$ $P < 0.05$, $**$ $P < 0.01$, $***$ $P < 0.001$.

3.3 Predictive Modeling

We built a transformer-based modal that predicts one team member's future remote controller action based on other team members' past physiological and behavioral data. We define the performance of the modal as the predictability of the participant. We found that team members' action predictability significantly correlated with overall performance (Figure 1 h). Teams with higher predictability exhibited better coordination and task outcomes, reinforcing the importance of this metric as a robust biomarker for team dynamics.

4 Discussion and Conclusion

Our study offers critical insights into designing and deploying AI systems for collaborative tasks. Combining physiological and behavioral analyses with predictive modeling highlights actionable strategies for enhancing human-AI teaming across diverse domains.

Despite advancements in AI development, including an AI teammate, even a WOz agent mimicking human-like behavior, often disrupts team performance and communication dynamics. Participants experience higher cognitive load and lower engagement in human-AI teams, highlighting the need for future AI development to account for human behavioral and physiological responses. Incorporating predictability as a biomarker offers a valuable perspective on team performance. High-performing teams exhibit predictable interactions that enhance coordination and efficiency. Future AI designs should focus on fostering human engagement and optimizing predictability through advanced multi-modal modeling.

References

[1] Yinuo Qin, Richard Lee, and Paul Sajda. Perception of an ai teammate in an embodied control task affects team performance, reflected in human teammates' behaviors and physiological responses. *arXiv preprint arXiv:2501.1533*, 2025.

[2] Yinuo Qin, Richard Lee, Weijia Zhang, Xiaoxiao Sun, and Paul Sajda. Physiologically-informed predictability of a teammate's future actions forecasts team performance. *arXiv preprint arXiv:2501.15328*, 2025.