CAREER: Task-Agnostic Worker-Assistance with Cognition-Aware Cyber-Physical Systems to Promote Ad-Hoc Worker-System Teaming

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Background and Objectives: Imagine a work setting where intelligent systems automatically perceive the workers' cognitive load, and provide real-time support, especially where workers switch from one task to another in an ad-hoc manner without any prior communication (e.g. as in the case of robot-swarm operators in search-and-rescue missions). However, state-of-the-art cognitive interventions rely on task-specific cyber-physical systems which use physiological sensor data to infer the cognitive load and present neurofeedback in the case of specific tasks. Therefore, PI Nadendla's long-term vision is to *develop low-energy, cognition-aware cyber-physical systems that detect cognitive overload and attention-switch intent, and design adaptive neurofeedback in a task-agnostic manner*. This proposal will pave a path towards achieving this vision by focusing on *robot-swarm control* setting. Specifically, the proposed 5-year effort has four primary objectives: (*i*) Classify worker's cognitive-load during multi-task jobs (e.g. robot-swarm control) using multi-modal bioelectrical data from wearable devices; (*ii*) Detect attention-switch intent between unknown tasks based on multi-modal bioelectrical data; (*iii*) Design task-agnostic neurofeedback based on worker's cognitive state and attention-switch intent predictions, and (*iv*) Develop an integrated educational plan with new courses at Missouri S&T, high-school visits, summer campus for K-12 students, and stakeholder workshops for training and research engagement.

Intellectual Merit: Based on the first three objectives, the research effort in this proposal is organized into three research thrusts. Thrust 1 will develop novel *task-agnostic neural networks (NNs) and few-shot learning algorithms* to detect cognitive overload at an individual level using *multi-modal bioelectrical data* (e.g. EEG and PPG) from wearable devices (e.g. smart headbands and watches) in the context of robot-swarm control missions. Thrust 2 will also develop novel NNs and few-shot algorithms (similar to Thrust 1) to detect *attention-switch intent* when the specific tasks incident to the attention-switch are unknown. Finally, Thrust 3 develops *task-agnostic neurofeedback based on audio interventions* (e.g. alerts/recommendations and noise-like stimuli with varying amplitudes) to help mitigate worker's cognitive overload under both normal and attention-switch events via integrating methods developed in Thrusts 1 and 2. Experiments will be designed using small ground robots (e.g. Jetbots) and mini-drones, and wearable devices (e.g. smart watch and Muse/Brainbit headband).

Education Plan: In addition to mentoring graduate and undergraduate students on proposed research activities, PI Nadendla will also develop a new course called *Ad-Hoc Cyber-Physical-Human Interaction*, and engage both graduate and undergraduate students on simple one-task project involving ad-hoc and intrinsic cyber-physical-human interaction. PI will also organize a two-day CyberMiner summer camp (through Kummer Center for STEM Education at Missouri S&T) to stimulate K-12 students, and a workshop to exchange bold research ideas and opinions across both academic researchers as well as diverse stakeholders from different application domains.

Broader Impacts: If successful, this proposal will radically transform human-system interaction in diverse applications such as driver/pilot-assist systems in semi-autonomous vehicles, multi-robot control (e.g. ground robots and drones) in search-and-rescue operations in disaster management and pest/disease control in agriculture, production worker support in manufacturing pipelines, and surgeons and other medical professionals in the healthcare sector.