Research Spotlight Deep Dives / Day 1: 22 June 2020, 2:00-3:30 EDT

Three parallel breakout sessions: Red, Green, Blue

Session 1
Red Breakout Room

Moderator: Addison Bohannon

Presenters	Affiliation / Role	Project Title	Abstract
Javier Garcia Kanika Bansal	Army Research Laboratory Cycle 1 internal ARL awardee	*Coordinated physiological representations of human-autonomy teams: characterizations and augmentations*	Individualized teaming technologies within heterogeneous human-intelligent agent teams will be critical to the success of US Army in the future complex, multifaceted, and dynamic battlespace. To enable these technologies, neural and other physiological signals may provide a unique glimpse into the covert mental events (or dimensions) of team members, especially as they interact with others, and will be crucial to the design and implementation of the individualized teaming technologies of the future. We propose that coordinated physiological representations underlying heterogeneous human-autonomy team processes may provide a framework for emergent team processes and targets for future "augmentation" technologies. Approaches and preliminary results will be discussed.
Jeni Kubota Jasmin Cloutier	University of Delaware Cycle 2 seedling awardee	*Impression Formation Social Neuroscience to Enhance Human-Agent Team Performance*	In this presentation, we will give a short introduction to our lab's work on the neuroscience of impression formation and how we plan to extend this work in the realm of decision- making to enhance human-agent team performance. In our seedling effort for Cycle 2, we plan to model how individual differences in data-driven multivariate brain networks supporting impression formation of human and non-human team members varying in competency status predict the emergence of various processes intrinsic to team performance during an escape room task.
Vasileios Maroulas	University of Tennessee External researcher	*Topological Artificial Intelligence*	Artificial Intelligence opens up new avenues that will help future generations to make accurate tactical decisions via human-agent teaming capabilities such as harnessing multisensory, multimodal, multiscale nonstationary, nonlinear and noisy (M^3N^3) physiological signals. However, current state-of-art methods often fall short as they rely on assumptions which violate the M^3N^3 nature. In this talk we will demonstrate how Topological Artificial Intelligence (TAI) analyzes these complex signals by relying on their shape peculiarities while respecting their nature. TAI views the signal analysis via topological data analysis lenses by tracking the evolution of homological features in signals over time intervals and producing summary representations, namely persistence diagrams. Due to the variability and uncertainty in these complex signals and their associated persistence diagrams, TAI develops a Bayesian framework, which allows us to

			incorporate prior knowledge from historical data, and/or past experience of an individual who is engaged in the human-agent team, and can be used as an input into a deep learner.
Stephen Gordon **Kevin King**	DCS Corp Cycle 2 seedling awardee	*Temporal Dynamics of Sustained Attention*	Many tasks require an individual to maintain heightened levels of attention for extended periods of time to achieve optimal performance. Sustained attention (SAT) is dependent upon multiple underlying dimensions and factors, such as fatigue, arousal, motivation, circadian rhythm, and novelty and difficulty of the task. Sustaining high levels of attention is difficult, and self-reports indicate that SAT waxes and wanes in response to task demands. The effects of the moderate waxing and waning of SAT on primary task performance are yet unknown, but the answer to this question has strong implications for heterogeneous team designs. Our prior work has explored novels ways to use passive physiological monitoring to mine information from a set of individuals. The goal of cycle 2 seedling is to extend these methods to investigate how SAT fluctuates in naturalistic settings and during true group interactions. The results of this investigation will inform the design of policies governing how nonhuman agents integrate within heterogeneous teams to leverage SAT. This work will focus on providing a moment-to- moment assessment of SAT from which further analyses may be derived.

Session 2
Green Breakout Room

Moderator: Katherine Cox

Presenters	Affiliation / Role	Project Title	Abstract
Catherine Neubauer	Army Research Laboratory ARL researcher	*Affective Computing and Human Sensing within Human Agent Teaming*	Affective computing is the study and development of systems and devices that can recognize, interpret, process and simulate human affect. Such technologies are designed to sense the emotional state of a user via sensors, cameras, various software and microphones. A variety of sources serve to help gather information from the human including facial expressions, speech, posture and even gestures, which can all signify a change in the user's emotional state. This multidisciplinary field is especially relevant within human agent teaming as autonomous agents/robots who serve as team members will be required to interpret the emotional state of their human counterpart and subsequently adapt its behavior to them, while also providing an appropriate response for such emotions. Furthermore, these interactions are especially important for the development of initial team trust and the eventually evolution of sustained team

			cohesion. During this spotlight the field of affective computing will be introduced in addition to outlining the specific requirements needed within human agent teaming. Finally, current work being conducted on affective computing within ARL HRED will be discussed.
Christoph Riedl	Northeastern University Cycle 1 awardee	*Micro and Meso Signatures of Success in Human-Autonomy Teams*	We are leveraging state-of-the-art sensing technology to theorize and model team communication at the micro- and meso-scales in order to develop virtual agents to participate in dynamic human-agent teams. Our team brings together leading experts in human physiology, non-verbal and verbal sensing, and dynamical team communication to collect a rich and comprehensive record of team communication dynamics across modalities and scales. We will present our current efforts to identifying streams of data that are predictive of team performance, and candidate windows where autonomy can intervene to improve team performance.
Michael Lewis	University of Pittsburgh Cycle 1 awardee / Cycle 2 seedling awardee	*Individual Differences in Adaptability in Human Agent Teams*	The ability to adapt to one another is one of the hallmarks of effective human teams. As autonomous agents engage in ever closer synchronization with humans it is becoming increasingly critical for agents to learn to adapt in similar ways. As part of the Army Research Laboratory's (ARL) STRONG (Strengthening Teamwork for Robust Operations in Novel Groups) program we are working to develop a predictive nexus of behavioral tasks and neurophysiological measures that can predict strategies and performance at team tasks in order to guide agent adaptation. Our work is bringing together two distinct strands of research: teaming performance on the Team Space Fortress (TSF) task and individual differences on a neuro-economic lottery task.
Gabriella Larkin	Army Research Laboratory ARL researcher	*Human-Agent Interactions for Intelligent Squad Weapons: Human-Computer Vision Collaboration*	The Army intends to leverage advances in AI, augmented reality (AR) and ubiquitous display technologies to continuously present information to the Soldier, with the intent of augmenting Soldier cognition. However, AR overlays will change Soldiers' visual interactions with their environments. Understanding how it changes these interactions may be key for creating collaborative human- computer vision. Here we discuss proposed research aimed at understanding how scene statistics contribute to perception, how AR alters those statistics and therefore influences scene perception, and how we can leverage that understanding to intentionally manipulate those statistics through a heads-up display (HUD) or other display to create the perceptual experience in a way that gives rise to human-computer vision collaboration.

Session 3
Blue Breakout Room

Moderator: Dave Hairston

Presenters	Affiliation / Role	Project Title	Abstract
Monica Nicolescu	University of Nevada Reno Cycle 2 seedling awardee	*From Heterogeneous Individual Capabilities to Emerging Teamwork: An Architecture for Effective Human-Agent Teams*	In this presentation I will first describe our team's relevant prior work and expertise in multi-human, multi-robot teams, intent recognition and natural language processing. Next, I will present the goals of our current Cycle 2 project, in which we propose to develop a novel approach for dynamic task allocation in an HR-Team that 1) models dynamic heterogeneity and human agent preferences, and 2) provides the ability to evaluate team performance based on the known capabilities and interactions of the individual agents in the team.
Radhakrishnan Balu	Army Research Laboratory ARL researcher	*Semantic Artificial Intelligence via Type Theory*	Humans employ three basic reasoning tools namely deduction, induction, and statistical inference in solving problems. A powerful AI based agent is desirable if incorporates all the three faculties and the field of semantic AI is concerned with engineering such systems. I will discuss an example of deriving a signal transduction pathway from T- cell proteomics data using first order predicates (deduction) and casting the solution as Bayesian inference (statistical inference). To augment such solutions with induction I will provide a brief introduction to type theory that is universal computation on one hand and universal math on the other side. Next, I will outline building AI systems using a specific flavor of type theory (Homotopy spatial notions based) that can be viewed as explainable AI (XAI) due to its logical content and geometric AI due to its geometric intuition that can enhance human-agent teamings. Finally, I will highlight related efforts at DoD in general and Army in specific on HoTT based solutions
Leslie DeChurch	Northwestern University Cycle 1 awardee	*Macro Signatures of Success in Human-Autonomy Teams*	Advances in AI and computer science are enabling intelligent, autonomous agents to join military teams. Our Cycle 1 STRONG project extends extant theories of human teams to human-autonomy teaming. In this presentation we share our year 1 efforts to understand the unique effects of autonomy (versus humans) on team processes and outcomes. In our first experiment, we explore the effects of poor performing autonomy on team functioning. We manipulate the identity of the poor performing teammate, comparing an autonomous robot to a human confederate, and compare the effects of each on emerging team processes, states, performance, and viability.

Brad Hayes	University of Colorado Cycle 2 seedling awardee	*Explainability and Shared Situational Awareness in Human-Robot Teaming*	Due to challenges in ensuring that autonomous teammates are helpful and safe, the practical deployment of collaborative robots remains largely infeasible. In this talk I will present an overview of my group's work toward realizing adaptive, communicative robot collaborators that both learn and dynamically assist in the completion of complex tasks. I will be focusing specifically on the importance of transparency, explanation, and justification, discussing new research targeting the establishment of shared expectations and shared situational awareness between humans and robots, with examples drawn from learning from demonstration and autonomous behavior coaching.

Research Spotlight Deep Dives / Day 2: 23 June 2020, 2:00-3:30 EDT

Three parallel breakout sessions: Red, Green, Blue

Session 4 Red Breakout Room

Moderator: Addison Bohannon

Presenters	Affiliation / Role	Project Title	Abstract
Nina Lauharatanahirun	Army Research Laboratory Cycle 1 internal ARL awardee	*Emergent cooperation in human-agent teams: the role of individual differences in social decision making under uncertainty*	Human-agent teams require humans and agents to make decisions cooperatively. Cooperation inherently assumes that the agent has some understanding of how human teammates make decisions under uncertainty. Neuroeconomic research has shown that individuals differ in how they make decisions under uncertainty. Since social interactions inherently involve uncertainty, risk preferences likely guide social interactions and emergent team states. Previous work also shows that human decision makers exhibit different biases in their risk preferences depending on whether they are dealing with social or non-social agents, and that these biases are represented in the brain. Our research attempts to examine (i) how human risk preferences may be used to guide social decision making in heterogeneous human-agent teaming and (ii) how agents can use knowledge of their human teammates' risk preferences to elicit cooperative team states.

Paul Robinette	University of Massachusetts Lowell Cycle 2 seedling awardee	*Emergent behaviors and trust cluster formation in human-agent teams*	We will present the fundamentals of emergent behavior in complex dynamical systems, including the relationship between emergence and observation scale, examined through several diverse examples. Next, we will focus on the building blocks of the Cycle 2 project, including the hypothesis that taskwork and teamwork occur at two distinct timescales. Specifically, we discuss that teamwork-related trust formation between agents and humans is dynamic and may occur at a slower timescale than taskwork proficiency. We propose to leverage this in a reinforcement learning framework to assess the slow timescale emergence of trust clusters in resource-constrained human-agent teams.
Evan Carter	Army Research Laboratory ARL Researcher	*Mobile videogame for studying human autonomy teaming*	ARL-HRED and collaborators at the University of New Mexico are developing a mobile videogame to study human autonomy teaming. We present results from earlier versions of this game that show clear variation in strategies, which might indicate opportunities for personalization of autonomous teammates, and we explain the current experiment aimed at developing adaptive capabilities.
X. Jessie Yang	University of Michigan Cycle 2 seedling awardee	*Trust-Driving Human-Agent Interaction: Modeling and Predicting Trust Dynamics*	In this talk, we will present the team's research expertise and prior work, the objectives of the seedling proposal, and future directions we would like to pursue. We will also talk about the collaboration opportunities (i.e, the gaps needed to be filled).

Session 5
Green Breakout Room

Moderator: Nick Waytowich

Presenters	Affiliation / Role	Project Title	Abstract
Derrik Asher	Army Research Laboratory ARL researcher	*Agents Leveraging Learning for Intelligent Engagement with Soldiers (ALLIES)*	Agents Leveraging Learning for Intelligent Engagement with Soldiers (ALLIES) is a research project that aims to establish and validate methods for training artificial intelligence (AI) agents to flexibly and optimally work with both humans and other computational agents in multi-agent systems. This effort combines multi-agent algorithms with learning methods to try and achieve superhuman-level group performance in homo- and heterogeneous agent-agent and human-agent teams. When considering collaboration among agents in multi-agent systems, individual and team measures of performance are used to describe the collaboration.

			Typically, the definition of collaboration is ill-defined and limited to a small class of tasks where coordination is necessary for task completion (e.g. two or more agents needed to lift a heavy object). In this work, we aim to present our approach that may be used to optimize group behaviors through the explicit measurement and re-implementation of collaborative metrics to guide agent behavior. We begin with the use of performance and corresponding behavioral data from computational learning agents in a 2D continuous predator-prey pursuit task in an open, bounded arena. Our recent achievements with this game theoretic environment have resulted in the identification of various metrics for collaboration quantification; namely, state-space perturbations for coordination profiles, ergodic spatial distributions, and policy duplication. The primary goal of this research is to: 1) identify metrics for collaboration that may be used to measure the degree of interdependence between the actions of cooperative agents, 2) implement the identified collaboration metrics into agent training (e.g., integrated into a reward or loss function) for explicit…
Katia Sycara	Carnegie Mellon University Cycle 1 awardee / Cycle 2 seedling awardee	*Agent Adaptation in Human Agent Teams*	We are developing agents that that are capable of real-time adaptation to individual human team mates to improve performance in human-agent teams. Our agents adapt by adopting a behavior policy that is trained to complement specific policies of different player types. After playing with a new human team mate, an agent identifies the type of the human player and selects an appropriate complementary policy to improve team performance. Our wok utilizes the Team Space Fortress (TSF) task where two vehicles form a team to defeat an adversary.
Efstathios Bakolas Luis Sentis	University of Texas at Austin Cycle 2 seedling awardee	*Emergent cooperative behaviors in human-robot teams induced by individualized and adaptive decision making, active sensing, and task allocation*	Our goal is to devise algorithms and models for adaptive decision making, active sensing and dynamic task allocation for mixed human-robot teams. Our approach promotes emergent cooperative behaviors via optimized and adaptive individualized behaviors. We also aim to model the effect of the so-called hidden (internal) states of humans (e.g., preferences, goals, beliefs as well as fatigue, cognitive load, attention span etc.) in the decision making process. Finally, we plan to create an environment for principled experimentation.
Chris Kroninger	Army Research Laboratory ARL researcher	*Adversarial Games in the DCIST CRA*	The Distributed and Collaborative Intelligent Systems and Technology (DCIST) Collaborative Research Alliance (CRA) is conducting research with ARL to support the control of heterogeneous teams. This talk will highlight research developing autonomous collaborative tactical behaviors. The efforts are extending game theory and the application of reinforcement learning to multi-agent, adversarial settings, like perimeter defense. The goal of the talk is to initiate follow-on discussions around opportunities to incorporate humans and human diversity with the STRONG CRA.

Session 6
Blue Breakout Room

Moderator: Brandon Perelman

Presenters	Affiliation / Role	Project Title	Abstract
Christopher Reardon	Army Research Laboratory ARL researcher	*Robust Human-Robot Teaming via Mixed Reality Multimodal Interaction*	In future Multi-Domain Operations, human Soldiers will be teamed with autonomous platforms in austere environments. This presentation will overview projects where a human teammate works cooperatively with a mobile robot. The human-robot interaction is mediated by multiple modalities of communication, including augmented reality and pose, gaze, and gesture tracking. Notably, this work eschews instrumentation of the environment (e.g., motion capture, GPS) for online frame registration between agents which would not be available in Army-relevant field environments which are unconstrained, uninstrumented, and unknown.
Tiffany Raber	Army Research Laboratory ARL researcher	*The Importance of Visualization in Understanding Quantitative Uncertainty: A Collaborative Research Experiment Overview*	Understanding quantified uncertainty through efficient visualization techniques is becoming increasingly important for the successful teaming of human and intelligent agents across many domains. For humans to make effective, well- informed decisions, visualizations must maximize the amount of critical information communicated in a way that complexity is not prohibitive of fast and accurate understanding. In this presentation, we will discuss common approaches to uncertainty in multiple domains and survey various visualization techniques. We will then dive into a current research experiment studying whether training with a given visualization of uncertainty leads to better performance with the practiced visualization, as well as if practice with a visualization of uncertainty transfers to other decision- making contexts.
Paul Sajda	Columbia University	*Physiological Signatures of Team Dynamics in a Distributed Sensory- Motor Task*	Our ability to integrate information sources to plan and make decisions depends on our physiological state, such as our arousal, level of fatigue and stress. Previous work by our group has shown correlations between physiological and cognitive state and how these interact to predict performance in a demanding sensory motor task. In this talk I will briefly review this work and discuss how we are building on this in our cycle 1 project. Specifically we have created a VR environment where a triad team must work together in a distributed control task. Team members include humans instrumented with physiological sensors as well as AI agents which have access to these data. Our goal is to investigate how physiological signals related to cognitive state change as team dynamics is varied and how how this information can be used to inform autonomy and provide “awareness” to autonomy regarding the state of human teammates.

Ying Choon Wu Tzyy-Ping Jung	University of California San Diego	*Harnessing Virtual Reality and Multi- modal Data to Study Team Dynamics*	Psychological momentum captures the dynamics of cognition, affect, motivation, and behavior in face of perceived task- related progress or inertia. This talk will explore how this phenomenon and other aspects of team dynamics can be studied using virtual Escape Rooms and visual search paradigms developed by our group. Our platform integrates virtual reality (VR) with heterogeneous biosensing capabilities, including electroencephalography (EEG), electrocardiography (ECG), eye-tracking, and motion capture. It also supports automatic tagging of fixated virtual objects, as well as in-game ecological momentary assessment (EMA). Our preliminary work compares fixation of targets versus distractors during ambulatory search.