# Layered Dynamics and System Effectiveness of Human-Autonomy Teams Under Degraded Conditions

[a]David A. Grimm, [b]Mustafa Demir, [a]Jamie C. Gorman, [b]Nancy J. Cooke, and [c]Nathan J. McNeese
[a]Engineering Psychology, Georgia Institute of Technology, Atlanta, Georgia, USA
[b]Human Systems Engineering, Arizona State University, Mesa, Arizona, USA
[c]Human-Centered Computing, Clemson University, Clemson, South Carolina, USA

*Project overview*. Teamwork can be defined as dynamic team interaction between two or more interdependent members to achieve a shared goal. Many studies have examined how coordination dynamics are associated with team effectiveness in the context of all-human teams (Gorman, Amazeen, & Cooke, 2010), and later, in human-autonomy teams (HAT)s (Demir, Likens, Cooke, Amazeen, & McNeese, 2018). HATs must have autonomous agents that act as effective teammates and help enable HATs to function as collaborative systems. Synergistic relationships among a system's human and technological components provide the basis for emergent systems-level outcomes. Layered dynamics, a recent empirical modelling technique aimed at achieving this objective (Gorman et al., 2019), considers reorganization of the sociotechnical system across individual components and the overall system. The current study examined layered dynamics of HATs during automation and autonomy failures and addresses how members of HATs interact with each other and technological aspects of the system.

*Design and Method*. We utilized a simulated Remotely Piloted Aircrtaft System (RPAS) Synthetic Task Environment with three heteregeneous and interdepedent roles: (1) a navigator, who created a dynamic flight plan and provided waypoint related information; (2) a pilot, who used this information to monitor and adjust settings. The pilot also communicated with the photographer to negotiate settings and enable proper conditions to obtain a good photograph; and (3) a photographer, who monitored and adjusted the camera to take good target photos, and provided feedback to the team. This study utilized a Wizard of Oz paradigm, in which the navigator and photographer were instructed that the pilot was a synthetic agent. However, the pilot was a highly-trained experimenter, in a separate room, who simulated an autonomous agent using limited vocabulary. There were 22 teams, and two participants were randomly assigned to the navigator and photographer roles. This task was comprised of ten 40-minute missions, and teams needed to take as many good photos as possible while avoiding alarms and rule violations. The primary manipulation was the application of three degraded conditions: (1) automation failure - role-level display failures, (2) autonomy failure - autonomous agent's abnormal behavior, and (3) malicious cyber-attacks - the hijaking of the RPAS, with the synthetic agent providing false, detrimental information. We symbolically represented RPAS using layered dynamics, and calculated entropy measures for each (Gorman et al., 2019): (1) *communications*: team members interacting within the chat system; (2) *vehicle:* states of the RPA, including airspeed/altitude, turns, fuel, battery, remaining film, and termperature level; and (3) *controls:* the interface controls between the RPA and the team members. To measure team performance, we used a time and coordination based metric for each target in each mission.

*Results and Discussion*. Our main findings were: 1) vehicle and communication entropy were higher than control entropy and were associated with better adaptation to both failures, and 2) control entropy had a negative association with initial status on team performance, while vehicle entropy had a positive association. These findings describe the tendency of low performing teams to anticipate targets poorly. This was due to a failure to interact with the technology in a timely manner. This lagged effect can be attributed to teams taking too long to interact with the technology. These findings shed light on how the layered dynamics approach can help understand team behavior under degraded conditions.

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