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ABSTRACT

In this Thematic Issue 'Human-Autonomy Teaming' of Theoretical Issues in Ergonomics Science, five U.S. military-funded research efforts are presented to discuss human factors issues in a variety of military human-autonomy teaming mission environments: dismounted infantry working with a small ground robot; intelligence analysis; human working with an intelligent agent to manage a team of heterogeneous unmanned vehicles; vehicle-mounted ground penetrating radar. The research issues addressed in this Issue are diverse – from display designs to operator performance and trust in the systems. The results and insights documented in these five articles should provide useful resources to researchers and practitioners working on intelligent and autonomous systems.

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Relevance to human factors/Relevance to ergonomics theory

The results and insights documented in this Thematic Issue should provide useful resources to ergonomics researchers and practitioners working on intelligent and autonomous systems.

Intelligent autonomous systems have become increasingly important in military missions (Defense Science Board 2016). Systems have been developed to assist war fighters in various tasks such as surveillance and reconnaissance, explosive detection and disposals, casualty extraction, supply transportation, building clearing and fire-fighting – just to name a few (Chen and Barnes 2014). As these systems become more intelligent and sophisticated – and autonomous – human-autonomy teaming has become a key issue to address. While there is a tremendous body of literature on human-automation interaction (Parasuraman and Manzey 2010), many of the previously established findings may not apply to contexts where machine agents possess advanced intelligence and greater autonomy (Lee 2008). The unique constraints associated with military settings (e.g. high criticality and potential lethality) also represent challenges that may not be dealt with in research conducted in non-military contexts. This Thematic Issue (TI) seeks to investigate human-autonomy teaming in a variety of military mission environments: dismounted infantry working with a small ground robot; intelligence analysis; human working with an intelligent agent to manage a team of heterogeneous unmanned vehicles; vehicle-mounted

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ground penetrating radar. The research issues addressed in this TI are also diverse – from display designs to operator performance and trust in the systems.

This Issue presents five U.S. military-funded efforts on human-autonomy teaming, and in these five papers, the authors discuss human factor issues that have to be addressed in order for human-agent teams to perform effectively in the real world with all its complexities and unanticipated dynamics. Three of these papers (Chen et al., Marathe et al. and Calhoun et al.) describe research efforts funded by the U.S. Department of Defense Autonomy Research Pilot Initiative (ARPI; Program Manager Dr D.H. Kim) – a three-year research program (2013–2016; Department of Defense 2013) to foster cross-service collaboration on innovative research and to advance autonomy capabilities in order to address future military mission requirements. This TI attempts to showcase the human science component of this research program. Also included in the Issue are two U.S. Air Force-funded works: a conceptual framework of autonomous agent teammate-likeness (Wynn and Lyons) and operator display designs for ground penetrating radar (Cummings and Quimby). Overviews of these papers are presented in the following.

Chen et al. (Situation awareness-based agent transparency and human-autonomy teaming effectiveness) describe a theoretical framework on agent transparency and their experimental efforts to investigate human performance issues associated with agent transparency. Drawing inspiration from Endsley's (1995) three levels of situation awareness (SA) – perception, comprehension and projection – the Situation awareness-based Agent Transparency (SAT) model describes the information that agents need to convey to the human in order to facilitate the shared understanding required for effective human-agent teamwork: namely, agents' current actions and plans, reasoning process, projected outcomes and uncertainty. Two projects supported by the ARPI are presented: Intelligent Multi-UxV Planner with Adaptive Collaborative/Control Technologies (IMPACT) and Autonomous Squad Member (ASM). Results from both projects consistently showed the positive effects of agent transparency on the human's task performance without increasing perceived workload. Research participants also reported greater trust in the agent when it was more transparent. The authors also discuss findings from the RoboLeader project, in which the human operator interacted with an intelligent route planning agent in a military convoy navigation setting. Finally, Chen et al. describe an expanded SAT model that incorporates teamwork and bidirectional transparency.

Marathe et al. (The privileged sensing framework: A principled approach to improved human-autonomy integration) also describe an ARPI-supported effort, Privileged Sensing Framework (PSF), and the authors challenge traditional views on human-centric automation with their novel conceptual framework on human-autonomy teaming. Specifically, while preserving the human as a primary authority, the PSF allows accommodations of human variability and enables dynamic integration of input from human and machine agents (i.e. dynamic 'privileging' information) based on characteristics of each agent, the task context and/or the performance goals. The PSF offers a provocative view that the human should be treated as a special – albeit critical – class of sensor, rather than as the absolute command arbiter, given all the variability in human performance. The utility of the PSF is demonstrated through a series of simulation experiments, which are described in the paper, along with methodological details available in the appendices.

Calhoun et al. (Human-autonomy teaming interface design considerations for multi-unmanned vehicle control) describe another ARPI project, IMPACT and the user interface design efforts associated with this project. The authors provide details about the processes of designing display and control elements associated with a play-based user interface in multi-heterogeneous-unmanned vehicles management (air, ground and surface) mission environments. Importantly, Calhoun et al. elaborate on the human factor principles that were employed during the design processes. These design efforts along with lessons learned documented in the article should provide valuable resources to human-autonomy teaming researchers and designers, particularly in areas associated with multi-robot management.

Wynn and Lyons (An integrative model of autonomous agent teammate-likeness) describe a novel construct, autonomous agent teammate-likeness (AAT) that seeks to capture human perceptions of machine agent's teammate-likeness. The development of the AAT framework was informed by prior research on human–human teaming and team processes, human–animal teaming and social aspects of human–machine/robot interaction. The authors describe the AAT dimensions (six dimensions identified), antecedents (human-related and agent-related) and outcomes (cognitive-affective and behavioural). Finally, to guide future research, the authors offer 14 research propositions associated with the AAT dimensions, antecedents and outcomes. As machines become increasingly intelligent and sophisticated, the development of this framework is timely, and particularly the research propositions provided in the article should provide useful suggestions to human-autonomy teaming researchers.

Cummings and Quimby (The power of collective intelligence in a signal detection task) describe the design process of a novel spatial display for a vehicle-based ground penetrating radar system and the user testing results comparing the effectiveness of this design and the original display. The authors analysed both the individual and collective human performance data, using the group (best vs. worst performers) Receiver Operating Characteristic curves for the latter. These data were also compared with data collected from two experts, who were involved in designing the radar system. The authors' approaches to user interface design and data analyses should be informative to the human-autonomy teaming community, especially in areas related to signal detection, such as military intelligence analysis.

In conclusion, these five articles cover a variety of human-autonomy teaming domains and topics. Although most of the research was conducted in military contexts, the implications for non-military applications can be far reaching (e.g. settings with high stakes and high operational tempos). The results and insights documented in these five articles should provide useful resources to researchers and practitioners working on intelligent and autonomous systems.

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Disclosure statement

No potential conflict of interest was reported by the author.

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