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Where's the Beef: How Pervasive Is Cognitive Engineering in Military Research & Development Today?

Organizer: Cynthia O. Dominguez, Applied Research Associates
Co-chair: Patricia McDermott, Alion Science and Technology

Panelists:
Lawrence Shattuck, Naval Postgraduate School
Pamela Savage-Knepshield, Army Research Laboratory
Christopher Nemeth, Applied Research Associates
Mark Draper, Air Force Research Laboratory
Kristin Moore, Naval Strategic Studies Group

Cognitive Engineering methods were developed to enable human factors practitioners to understand and systematically support the cognitive work of people working "at the sharp end of the spear." Military members for whom DoD acquisition organizations develop systems are the quintessential "sharp end of the spear." This panel is proposed to share present-day experience from military and industry reflecting how pervasively Cognitive Engineering is contributing to research and development for the highly complex military systems being operated under conditions of stress, time pressure, and uncertainty today. The implications for human factors practitioners will be highlighted, both in terms of practices to continue and areas for improvement.

OVERVIEW

About 15 years ago, several leaders in the field of Naturalistic Decision Making (NDM) and Cognitive Systems Engineering (CSE) joined together to propose HFES form a new technical group (TG). This group was an idea whose time had come; the support and energy of the TG and the number of people drawn to it were unanticipated. Over the next five years, the Cognitive Engineering and Decision Making (CEDM) TG became the largest TG in HFES; it currently has well over 1000 members. Through the work of its supporters, the TG succeeded in creating a journal to publish the work of its members, the Journal of Cognitive Engineering and Decision Making. The TG was (and is) a reflection of events in the world. The aftermath of the USS Vincennes' tragic shoot down of an Iranian airbus led to Congressional hearings and new programs, such as Tactical Decision Making Under Stress (TADMUS), to consider cognitive performance in design and training.

Events in the world today mandate accounting for cognitive work in the design of systems and training more than ever before. Unprecedented levels of automation often require unforeseen levels of human minders to ensure safety and mission accomplishment. Technology capabilities lead to a proliferation of information technology that may claim to support situation awareness and decision making, but lacks the design process and up-front research to understand the user's actual problem space and operational constraints. The result is "drive-by fieldings," technology bought and paid for based on a vendor's convincing PowerPoint that fails to connect need and solution. At best, it collects dust on a shelf. At worst, it results in threats to property, health, and life.

Work is more cognitive than ever, especially for military warfighters. This fact has been recognized in military acquisition guidance. Department of Defense (DoD) instruction 5000.02 is the document which provides guidance to all services in translating joint capability needs into well-managed acquisition programs. In its latest, December 2008 edition, in the enclosure on Human Systems Integration (HSI), this DoD instruction states "the program manager shall take steps (e.g., contract deliverables and government/contractor integrated process teams) to ensure ergonomics, human factors engineering, and cognitive engineering are employed during systems engineering over the life of the program to provide for effective human-machine interfaces and to meet HSI requirements."

How are the CEDM Technical Group and wider community helping to achieve this need, recognized by the DoD, to account for cognitive work in the design of systems and training? This panel will present a current view from individuals across the military services and industry as to whether the intention behind the CEDM TG is well established and functioning. Where are the

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gaps? What future efforts might be to improve the state of the art? These run the gamut from methodological questions to outcomes and acceptance.

Methodological Questions

Are cognitive task analysis methods being employed? Is there an acceptance of the important qualitative data that these methods yield towards understanding of operational needs and development of requirements? How well are researchers able to translate findings into usable requirements – for the HSI community and the larger acquisition organization? Are the military laboratories applying CSE and NDM models?

Outcomes

How well is the importance of collaboration across individuals and distributed locations supported by design? Are humans considered to be a resilient part of complex sociotechnical systems, requiring collaborative and adaptive automation partners, rather than expensive resources to be automated? Have we evolved past the measurement of mental workload in our test programs towards understanding why workload is too high or too low?

Acceptance

How strongly do program managers value approaches that ensure humans build expertise towards engaging the complex systems they must manage, especially when systems fail? How well do CSE practitioners demonstrate the value of understanding the human as a critical component of complex systems?

PANEL SUMMARY

Once a research field or approach has been in use for a period of time, it is suitable to take stock and evaluate its usefulness and more importantly, its impact on those that it seeks to aid/assist/support. With these questions, we seek not just a yes or no response but "how well" and "how better." Human factors practitioners will have several take-aways from this panel. They will gain an awareness of the impact of CSE on current military research and acquisition practice. This panel will also serve as a call to action to address identified needs to improve the state of the art, and it can enlighten the community about which practices and approaches are particularly useful in military acquisition settings, and therefore should be more broadly adopted.

LAWRENCE SHATTUCK
NAVAL POSTGRADUATE SCHOOL

Dr. Lawrence Shattuck is a Colonel is the U.S. Army, Retired and a Senior Lecturer at the Naval Postgraduate School in Monterey, CA.

The first article I read at the beginning of my CSE graduate education was authored by Woods and Roth (1988). I learned that CSE was: about complex worlds; ecological; about the semantics of a domain; about improved performance; about systems; about multiple cognitive agents; problem-driven. Upon completing my graduate work, I taught CSE concepts and methods to Cadets at the US Military Academy, engaged in militarily relevant CSE research, and published the results of that research. Although the work was well-received by my peers, I believe it had virtually no impact on the development of any actual military system.

I retired from the Army a decade after completing my graduate work and moved into the world of HSI at the Naval Postgraduate School. It was there I grasped that HSI practitioners work within the acquisition process and alongside program managers and systems engineers and, if I wanted to impact the design of a warfighting system, I needed to work within that framework. The International Council on Systems Engineering (INCOSE) defines HSI as "the interdisciplinary technical and management processes for integrating human considerations within and across all system elements; an essential enabler to systems engineering practice." Most HSI practitioners agree that the domains of HSI include Manpower, Personnel, Training, Human Factors Engineering, Survivability, Habitability, Safety, and Occupational Health. Having worked in the fields of both CSE and HSI, I recognize the contributions that each discipline can make to the research, development, and acquisition of complex systems for our nation's Warfighters.

HSI practitioners are knowledgeable with respect to the DoD acquisition process. They understand where a system is in that process and the activities appropriate for each phase of the process. They can speak the language of program managers and systems engineers and work within program constraints and/or enablers such as cost, schedule, and risk. HSI practitioners leverage all of the domains of HSI to achieve the best possible total system performance by conducting tradeoff analyses. For example, an HSI practitioner may respond to a decision to limit the number of Sailors on a new ship (i.e., the manpower domain) by recommending modifications to one or several of the other domains (e.g., require more skilled Sailors (personnel domain); modify training practices (training domain); automate selected activities (human factors domain), etc.). And,

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HSI practitioners are concerned with both cognitive and physical aspects of warfighting performance. Although many warfighting activities are cognitively demanding, many others remain physically demanding (e.g., shipboard damage control; maintenance activities; search and seizure missions; etc.).

While HSI practitioners' activities must remain rather broad and shallow, CSE practitioners provide the necessary depth in critical areas of the acquisition process. During the past three decades, CSE practitioners have developed empirical and observational methods that are directly relevant to Warfighters. For example, many CSE practitioners are skilled in ethnography, a research method that is invaluable for examining how Warfighters perform using legacy systems. And, prior to the decision to pursue a material solution, a capability-based assessment (CBA) is conducted. Knowledge elicitation and cognitive task analyses are two activities that contribute significantly to a successful CBA. CSE practitioners know how to construct and employ microworlds in the absence (or in lieu) of operational systems. Early in the acquisition process, prior to useful prototypes, CSE practitioners can study proposed concepts or designs. One of the most useful tools at the disposal of CSE practitioners is the vast amount of empirical findings that have been compiled over the last 30 years. However, the practitioner must be willing and able to employ this tool swiftly, in a manner that provides a "close enough" answer to a question posed by a harried program manager or a systems engineer. "Give me six months and half a million dollars for a little more research" is not an acceptable response to such a question.

In summary, CSE can make a value contribution to the research, development, and acquisition of complex systems for our nation's Warfighters. But, if that contribution is to be more impactful than it has been, CSE practitioners must have a modicum of knowledge about acquisition, program management, and system engineering. I am not suggesting CSE morph into HSI. There is clearly a need for both disciplines. CSE is all about systems in context. The discipline stands a much better chance impacting our warfighting systems if it works within the context of the structure that develops those systems.

PAMELA SAVAGE-KNEPSHIELD
ARMY RESEARCH LABORATORY

Dr. Pamela Savage-Knepshield is the Chief of the Human Factors Integration Division in the Army Research Laboratory (ARL) Human Research and Engineering Directorate (HRED).

One of the primary missions of ARL HRED is to provide HSI support to acquisition programs through a systematic consideration of the impact of materiel design on Soldiers throughout the system development process. The Army's HSI Program, MANPRINT, was initiated in 1984 to address persistent problems that were plaguing the Army – newly developed systems were not meeting human performance requirements and their user interfaces were so complex that greater numbers of more highly skilled Soldiers were needed to operate, maintain, and sustain them. Six years later, it became recognized that automated information systems were not being designed to maximize Soldier-system interaction, and the MANPRINT mission was expanded to incorporate them. During the past 20 years, ARL HRED has been involved in varying degrees in the design, development, test, and evaluation of over 200 systems. Systems supported have ranged from communications and command and control systems to air defense systems and aviation and ground vehicle platforms. Our workforce is geographically distributed at over 20 locations to be co-located with the various Army Centers of Excellence and Program Managers, who are also geographically dispersed.

Although the MANPRINT Program specifies policy and provides oversight to ensure that government and defense contractor MANPRINT practitioners are involved in materiel development, the level of effort expended varies across programs. Variance is a function of several factors including: the point in the acquisition process at which the practitioner is engaged in the design process, the amount of funding allocated for the effort, and the willingness of the Program Office and its contractors to engage in cognitive engineering and Soldier-centered design activities. Ideally, human performance parameters should be specified in requirements and contractual documents in the same manner as any other component of the system. However, in actual practice, this has not always materialized.

Efforts to address this shortcoming within the Army have been recently initiated by the Office of the Deputy Chief of Staff, G-1 MANPRINT Directorate, ARL HRED, and the Training and Doctrine Command, which is the organization responsible for leading Army requirements determination. This initiative, referred to as "Moving MANPRINT to the Left," will ensure that cognitive engineering is included in early system engineering planning efforts and during analyses of alternatives and other pre-systems acquisition activities. Since we are reliant on Program Managers for funding, we are not involved in the process until a program is initiated which is too late to impact requirements development and often too late to have the impact on design that we could if we were involved earlier.

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Furthermore, our design impact at this late stage may have a significant cost associated with it. Additional challenges, which will be discussed, include MANPRINT involvement in rapid fielding initiatives (equipment designed to meet urgent needs in theater), new equipment designs being assessed at the Network Integrated Evaluation, and the design of effective human-system interaction for automated systems that make decisions with limited human intervention.

CHRISTOPHER NEMETH
APPLIED RESEARCH ASSOCIATES

Dr. Christopher Nemeth is a Principal Scientist and the Group Leader for Cognitive Systems Engineering at the Cognitive Solutions Division of Applied Research Associates, Inc. Dr. Nemeth offers a perspective from the industry side of the issue.

In our recent experience with military applications, we have encountered a variety of circumstances related to system acquisition and human performance. In working with those in the DoD acquisition process we have encountered the presumption that data on behavioral performance is sufficient. However, in today's high-hazard complex work, cognitive performance is as critical, if not more critical, than behavioral performance. Often, there is an interest in physiology and quantifiable measures. These types of human metrics may appeal to engineers because they are readily observable. You can perceive the measurement of arm reach and understand the implication for system design. The interest in physiology and quantifiable measures are seen as the route to understand cognitive work. The reality is that the sum of these measures does not explain cognitive performance.

Cognitive requirements need to be defined for the systems or tasks, depending on the level of analysis. CSE is a means to account for cognitive work in high hazard work domains. I will describe our experience in a recent year and a half project for the Chief of Naval Operations on behalf of the Naval Expeditionary Combat Command. The results illustrate the potential and prospects for CSE and its use in military applications. Further reflections on the topic are included in a recent special issue of the journal Cognition, Technology and Work, "Adapting to Change and Uncertainty" (Nemeth, 2011). In particular, I will elaborate on the potential for CSE to understand how operators successfully deal with change and uncertainty and the implication for designing complex adaptive systems.

Currently, not all systems acquisition processes allow for the consideration of cognitive requirements. And if it is not part of the process, it doesn't occur. TADMUS was watershed work but its legacy did not become an institutionalized part of the acquisition process. Despite the value and relevance of TADMUS, without changing the acquisition process, the lessons have the potential to dissipate after a number of years.

MARK DRAPER
AIR FORCE RESEARCH LABORATORY

Dr. Draper is a Senior Research Engineering Psychologist in the 711 Human Performance Wing of the Air Force Research Laboratory.

The US Air Force (indeed the entire DoD) is changing the way it conducts operations due to the changing nature of war. Future threats will be more clandestine, distributed, and decentralized while our force structure is shrinking. The focus will be maximizing the effectiveness of a smaller, agile force through increases in unmanned systems, autonomy, and cyber operations with an emphasis on improving the flow of data to decisions. Thus, CSE will be critical in the design of these more highly automated systems in order to effectively extend the capabilities of future Airmen. This presentation will focus on how well CSE principles, methods, tools and techniques are being applied for this purpose, within the AF Research Laboratory (AFRL) and across the acquisition community.

The 711 Human Performance Wing of AFRL certainly subscribes to the guiding tenet of cognitive engineering that consideration of the users and the tasks they will be performing with the aid of a computer system should be central drivers for system design. In general, however, the application of CSE across research projects is somewhat variable and informal versus systematic and rigid adherence to particular methods. This is likely due to several factors, which will be discussed. In addition, some methods, tools and techniques are applied far more frequently than others. The results of an informal sampling of research projects within the 711th Human Performance Wing will indicate which CSE methods are being applied most frequently and which seem to only exist in niche areas, if at all. It appears that the application of CSE methods drop substantially as system development enters the acquisition process. Interviews with Program Office officials will reveal several reasons for this, including tight schedules and limited resources available for guidance and oversight. Lastly, a few ideas will be offered as to how to improve use of CSE within the AF, especially within the acquisition community.

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KRISTIN MOORE
NAVAL STRATEGIC STUDIES GROUP

Dr. Kristin Moore is a human factors practitioner at SPAWAR Systems Center Atlantic, embedded as a technology fellow for the Chief of Naval Operation's Strategic Studies Group in Newport, RI.

Cognitive engineering is a focus area that is often talked about but not frequently funded in systems acquisition. Program managers that I have worked with in the Navy often state that they have no funding for cognitive engineering and human factors because no requirements specifically call out these practices. When I ask about adding them to requirements documents, I'm told they are too subjective and there are no objectively measurable metrics to include. This illustrates the circular logic that many human factors practitioners have to overcome in order to both produce meaningful results and have them valued within the organizational framework.

Although there is still a long way to go, I believe that more systems engineers and project managers are including cognitive engineering practices in their programs. It is simply no longer something that they can ignore. I have personally seen a very positive transition in the relatively short amount of time I have been working for the Navy. When I began working on programs I was the only human factors team member and was included as a member of the test and evaluation team. I have since been asked to participate on programs as the human systems integration lead, an equal member of the systems engineering integrated process team (IPT) alongside the test and evaluation lead and others. My systems command has continued to hire additional human factors and cognitive engineering practitioners to support numerous programs. These gestures speak volumes to the increasing importance program managers are placing on the field.

While DoD 5000.02 has been helpful in bringing attention to cognitive engineering and human factors practices, it is still only guidance and does not specify how programs can go about executing these principles over the lifetime of the program. More commands are hiring qualified human factors professionals and seeing the tangible impact of their expertise. While this is a positive trend, human factors professionals cannot act in a vacuum, lest they become another "check in the box" for a program. The appropriate execution of cognitive engineering principles requires the buy-in and active participation of the entire systems engineering team. The acquisition process could be greatly improved with three main areas of improvement in the short term:
1) Explicitly identifying user capabilities for the developer; 2) Applying front-end cognitive engineering practices to help steer the design process; and 3) Working to identify objective cognitive engineering-related requirements.

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