Cognitive Engineering and Decision Making: An Overview and Future Course

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Abstract: The field of cognitive engineering and decision making (CEDM) has grown rapidly in recent decades. At this writing, it is the largest technical interest group within the Human Factors and Ergonomics Society. Work that falls into this area of research and study is also widely practiced across Europe and in countries around the world. Along with this growth, there is a significant need for a peer-reviewed journal that focuses specifically on CEDM as a science and applied discipline. The *Journal of Cognitive Engineering and Decision Making* is intended to meet that need. It will cover current research, theory, and practice in ways that not only provide for the sharing of information across interested parties but also serve to move the field forward. This will advance theoretical bases; address outstanding scientific challenges; set new courses and directions; address methods, measurement, and methodological issues; and show useful applications of this work in the development of operational and training systems in many domains that are of significance to society, government, and business. In this article, we provide background on the CEDM field and its areas of research. We use this as a platform for further specifying the scope of this journal along three technical tracks. Objectives are identified for each track as it supports the overall mission of the journal. Finally, we provide information on an electronic companion to the journal that is intended to support advances in the field through dialogue and access to further resources.

Overview of the Field

Cognitive engineering and decision making (CEDM) involves the study of cognitive work and the application of this knowledge to the design and development of technology. This research has resulted in a large body of work that is employed by practitioners in a wide variety of domains. Largely driven by the increased cognitive demands inherent in sociotechnical systems that employ high levels of technology (e.g., computerization and automation), the need arose for those practicing human factors/ergonomics to exceed the boundaries of specifying the human-machine interface at only a surface level (i.e., its perceptual and physical characteristics). Designing

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Journal of Cognitive Engineering and Decision Making, Volume 1, Number 1, Spring 2007, pp. 1–21

human-machine systems that truly support cognitive work requires a substantially different class of human factors approaches, one that also specifies the logical structure, design, and functioning of the technologies as interactive components with the human operator. The CEDM field incorporates an understanding of human cognition in many types of tasks and often in the presence of teamwork. Efforts to address this need have fallen under a number of different topic areas and communities of practice, which developed in parallel but largely focus on similar concerns and which constitute the makeup of the CEDM field. These various areas of the CEDM field are described next.

Cognitive Systems Engineering

The term *cognitive engineering* (CE) can be traced to work by Norman (1981, 1986) and Hollnagel and Woods (1983). CE emphasizes the application of knowledge and techniques from cognitive psychology to the design of human-machine systems (Woods & Roth, 1988). Cognitive Systems Engineering (CSE) is a variant of CE that emerged at about the same time. CSE offers a broader, systems perspective to the analysis and design of human-machine systems (Hollnagel & Woods, 1983). The unit of analysis in CSE encompasses the phenomena that emerge at the intersection of people, technology, and work. Humans, technology, and work are analyzed as a joint cognitive system (Woods & Hollnagel, 2006). People are viewed as goal directed agents that adapt to the demands of the work settings and the affordances (and limitations) of the technology available. The study of joint cognitive systems is a process of discovering how the strategies and behaviors of people are adapted to the purposes and constraints of the field of activity. This includes uncovering how people adapt to exploit affordances in the environment and to work around complexities as they pursue their goals.

Woods and Roth (1988) outlined several key aspects or features that need to be explicitly taken into account by CE/CSE: (a) the importance of context, examining what people actually do given real-world situations, goals, and constraints; (b) the importance of the accessibility and utilization of situation-relevant knowledge and its impact on cognitive behavior; (c) the need to rely on a systems perspective in analysis and design that incorporates an active role for humans in shaping their environment; (d) the need to incorporate complex systems and complex problems into research paradigms to achieve useful and applicable research and design results; and (e) a consideration of multiple cognitive agents, both human and machine, that may interact as a basis for characterizing domains. Improving performance in these environments calls for understanding the full problem-solving context and the challenges inherent in it, examining how people actually behave, and the knowledge and strategies they employ when faced with real-world demands and when working in conjunction with available tools. This can be achieved through cognitive task analysis and cognitive work analysis methods as a basis for engineering systems.

"The focus of CSE is on how humans can cope with and master the complexity of processes and technological environments, initially in work contexts, but increasingly also in every other aspect of daily life" (Hollnagel & Woods, 2005, p. 1).

Hollnagel and Woods (2005) emphasize that the focus of CSE is on analyzing *what* a joint cognitive system does and *why* it does it – in terms of the external constraints and affordances that shape performance – rather than explaining *how* it does it at a detailed cognitive processing level. This emphasis on a macrolevel analysis of the joint cognitive system and the forces that shape its performance contrasts with some other approaches within the CEDM field, which work to provide detailed descriptions of the cognitive processes and functions that underlie performance.

Naturalistic Decision Making

The study of *naturalistic decision making* (NDM) has also evolved as a focused effort to describe how people make decisions in the real world. While some earlier researchers described decision making as being based on recognizing patterns in the situation that were matched to known patterns in memory (e.g., DeGroot, 1965; Kuhn, 1970; Mintzberg, 1973; Dreyfus, 1979, 1981), the area of NDM largely blossomed around the work of Gary Klein (1989, 1993, 1986). NDM rejects certain previous research on decision theory (e.g., utility theory) as being largely normative instead of descriptive; therefore, such research fails to capture critical aspects of how people – particularly experts – actually make decisions. NDM specifically seeks to provide rich descriptions of how people make decisions in the real world, as opposed to within artificially contrived and constrained laboratory tasks. The environments on which NDM focuses may encompass ill-structured problems, uncertainty, time stress, risk, multiple and changing goals, multiple individuals, and experienced decision makers.

Although NDM focused originally on the human as a decision maker, as opposed to the more general cognitive agent discussed in the CSE literature, both fields have broadly defined this role to include problem formulation (and reformulation), situation assessment, goal definition, plan generation and evaluation, plan monitoring, and adaptive behaviors. Both fields also stress the importance of real-world task settings for capturing and understanding the true nature of human cognition. NDM has been very focused on cognitive processes in describing how people perform cognitive work. In the NDM approach, it is the analysis of knowledge and skills underlying novice and expert performance that provides the basis for identifying *leverage points* for improving performance and specifying requirements for training and decision aids (Crandall, Klein, & Hoffman, 2006).

More recently, NDM has expanded to include the analysis of macrocognition (Klein, Ross, Moon, Klein, & Hollnagel, 2003). Similarly focused on the behavior of experts, it concentrates on developing a description of a wide range of cognitive functions. This focus is somewhat broader than historical NDM research and includes processes such as attention management, mental simulation, common ground maintenance, mental model development, uncertainty management, and course of action generation. Klein et al. (2003) described a key collection of functions, including problem detection, sensemaking and situation assessment, coordination, planning, adaptation and replanning, and naturalistic decision making. In macrocognition research, these facets of the cognitive experience are contrasted with the microcognitive processes studies of traditional psychology (e.g., memory and attention) and are thought to be the basis for causal descriptions of how fundamental mental operations trigger one another.

Ecological Interface Design

Ecological interface design (EID) and *cognitive work analysis* (CWA) form another branch of relevant work that falls into the CEDM field. EID was formulated by Rasmussen and Vicente (1989) based partially on the work of Gibson (1979) and the broader ecological psychology tradition, and also on the experiences of Rasmussen and his colleagues in the process control industry at the RISØ National Laboratory of Denmark. EID rejects the information-processing view of traditional psychology and instead views aspects of the world as being seen directly in terms of their affordances to the operator. "Ecological approaches tend to focus on meaning in terms of functional significance" (Flach & Hancock, 1992, p. 1057). Like NDM, EID has diverged from the practice of experimental psychology that often separated the study of cognitive functions from the environment and the complex tasks in which the tasks normally occur (Flach, 1990). Like CSE, ecological EID explicitly avoids discussion of cognitive constructs (such as attention or memory) and instead focuses on the attributes of the work domain (its structure and constraints) and the affordances which that domain offers based on operator goals.

EID and CWA were developed as a means of carrying out system design based on ecological psychology tenets and on work domain models (Burns & Hajdukiewicz, 2004; Rasmussen, Pejtersen, & Goodstein, 1994; Vicente, 1999). These work domain models focus on operator goals via a means-ends analysis and an abstraction hierarchy that describes the system to be controlled or the work domain. CWA directs designers to create interfaces that reflect the work constraints captured in this analysis and to group information based on the means-ends analysis (see Hoffman & Lintern, 2006). In practice, EID/CWA work has concentrated more on analysis and design and less on descriptions of cognitive processes or experimental approaches to the study of cognition.

Mental Constructs

A significant amount of work in CEDM has also been conducted by a community of practice that focuses on exploring and enhancing key mental constructs such as situation awareness, mental workload, and mental models – all of which are seen as fundamental contributors to effective human functioning in complex systems. The mental construct area of CEDM includes work consistent with information-processing models of human cognition (Wickens, 1992) but also embraces the wider range of processes and functions examined in NDM and macrocognition research. It contrasts with the CSE and EID approaches for describing and predicting human interaction with complex systems by dealing more with internal aspects of cognition and how they affect systems design.

Mental models are a cognitive construct that remains a focus of much CEDM literature (Bainbridge, 1981; Johnson-Laird, 1980; Rasmussen, 1981; Reason, 1988;

Rouse & Morris, 1985). Capturing and representing the mental models of individuals has proven difficult, yet mental models are believed to play a central role in guiding human interaction with complex systems. Although CEDM often advocates the design of systems to support people's mental models, the difficulty of specifying those models a priori has often made this difficult to put into practice.

While the concept of *mental effort* dates from early experimental psychology, the study of mental workload became a major focus in the 1970s, in particular measuring and reducing mental workload in complex and demanding environments such as aviation (Hancock & Meshkati, 1988; Hart & Sheridan, 1984; Moray, 1979). In addition to work that addresses automation approaches to reducing mental workload, current work in CEDM often focuses on the design of displays and multimodal interface approaches based on *multiple resource theory* (Wickens, 1992) as a means to reduce mental workload and improve the design of systems.

Vigilance in low-workload environments has also remained an issue of research focus for the CEDM field even though its roots can be traced back many decades (Macworth, 1948). This work continues even today, in areas such as security screening, aviation, and military systems. The effect of automation on vigilance and complacency has kept this stalwart of human factors in the stream of current relevance.

Beginning in the late 1980s, a focus on *situation awareness* (SA) began to emerge as a key cognitive construct of interest, springing from the terminology and challenges of the aviation field. Situation awareness, an operator's mental representation of the world around him at any given time, forms a key construct that largely guides moment-to-moment decision making and performance in complex systems (Endsley, 1988). Situation awareness differs from mental models in its emphasis on the dynamic and changing situational features that an operator must keep up with. By contrast, mental models evolve more slowly than situation awareness, which can change from moment to moment.

Research on situation awareness has examined how people develop and maintain accurate and up-to-date mental representations of the systems they operate and the world in which they and their systems operate, as well as designing systems that support that critical construct. In a sense, NDM picks up where SA leaves off, dealing with how the decisions are made based on SA; this makes SA largely complementary with NDM's focus on decision making. Approaches to SA research have a variety of theoretical ties (Adams, Tenney, & Pew, 1995; Durso & Gronlund, 1999; Endsley, 1988, 1995b). Often employing a more experimental approach than NDM or CSE, work in situation awareness, like that on mental workload, has also focused on measurement as a means of furthering research on the topic and evaluation of system designs (Endsley, 1995a; Endsley & Garland, 2000b).

Under the premise that a key means of improving decision making and performance in complex, dynamic systems lies in improving and supporting operator situation awareness, SA-oriented design (SAOD; Endsley, Bolte, & Jones, 2003) has been developed to create systems that enhance operator SA. This system is based on Endsley's theoretical model of SA and the body of research on SA conducted across many domains. SAOD provides a methodology for design that is mapped to large-scale systems development, and features (a) SA requirements analysis using goal-directed task analysis; (b) SA design based on 50 design principles, which include specific design guidance derived from the theoretical model in addition to principles for designing to deal with system complexity, uncertainty, automation, alarms and diagnosis, and team operations; and (c) SA measurement for system evaluation. SAOD training programs are similarly developed based on this work (Endsley & Robertson, 2000; Kaber et al., 2005; Riley et al., 2005; Strater, Jones, & Endsley, 2003).

In contrast to NDM and CSE, work in the mental construct area of CEDM is often more experimental in nature. It relies on studies in natural settings or complex simulations, coupled with the controlled presentation of conditions and measurement of mental constructs to further define these constructs and how they interact with technologies to produce human-system performance. Unlike laboratory experiments in traditional psychology, experimental work in CEDM emphasizes the importance of task realism (per the relevant domain) and the incorporation of domain experts. Virtual reality systems may be used to deliver high levels of fidelity in real-world task simulations and, at the same time, allow for a high degree of experimental control to better elucidate the mediating effects of system design features.

Research on mental constructs can be seen as largely complementary with the more descriptive approaches in CEDM, including CSE; it makes it possible to test and explore, in more detailed and objective ways, the behaviors and hypotheses generated in the field through more subjective observations. This area of CEDM is also heavily involved in system design – it emphasizes testing the effects of various technology implementations on the emergent properties of the human-machine system and its performance characteristics. Thus, mental construct measurement has formed an important part of this area of practice, along with the development of simulations and synthetic environments for valid and generalizable testing of concepts and system designs. Work on mental constructs also frequently serves as a foundation for other CEDM work.

Computational Modeling of Cognition

Arising from the body of work on human cognition in using interactive systems (Card, Moran, & Newell, 1983), computer models and simulations of cognition have grown in popularity as mechanisms for describing human behavior with tools and support systems, for predicting human-system interaction during the development of new systems, and as a means of testing and further developing cognitive theories themselves. This work features a wide variety of modeling approaches, including ACT-R (Anderson & Lebiere, 1998), EPIC (Meyer & Kieras, 1997), GOMSL (John & Kieras, 1986), SOAR (Newell, 1990), IMPRINT (Allender et al., 1997), and Bayesian networks (Zacharias, Miao, Illgen, Yara, & Siouris, 1996).

Historical work in this area has focused on interface evaluations using these cognitive modeling approaches or on selecting among design alternatives for actual applications. Studies such as that by Gray, John, and Atwood (1993) have validated task-specific cognitive models against human performance data and provided successful bases for decision making on system alternatives. Others have developed cognitive models as explicit hypotheses on aspects of cognition or behavior in particular contexts, including human performance with automated systems (Kieras & Meyer, 1997). These models have been tested against human performance data to determine whether the assumptions about memory processes or overarching cognitive strategies coded in the models, for example, result in computer behavior that mimics that of the human. This work has been useful for gaining further insights into cognitive constructs as well as revealing limitations of specific modeling approaches.

Recent advances in software tools for coding and running computational simulations of cognition in context have dramatically increased the accessibility and applicability of specific approaches – for example, ACT-Simple (Salvucci & Lee, 2003), G2A (St. Armant & Ritter, 2004), and EGLEAN (Kieras & Wood, 2002) – for describing and predicting human behavior with complex systems. These tools can serve to accelerate the cognitive model-based evaluation of interfaces from a usability perspective and may advance the pace of discovery of aspects of cognition.

Cognitive modeling has a rich pedigree in the mental construct area of CEDM and traditional psychology research. It has emerged as an important area for usability evaluation and mental construct development. This direction of work may provide a bridge between the more descriptive approaches of CEDM – including CSE and CWA – with the mental constructs area in the future.

Automation

As our previous discussion makes clear, all of the communities of practice that CEDM represents focus (at least in part) on the design of better information technologies to support cognitive work. This includes those who work extensively on automated systems and decision support systems (DSS), to cite two examples. Although complex technologies and systems underlie the work that is studied in much of the CEDM field, automation and DSS pose a particular challenge for human cognition. They form unique (semi-) intelligent machines of their own with which operators must interact in order to accomplish their work, thereby creating unique challenges for the operator, who must understand and effectively interact with the automation (Wiener & Curry, 1980). This often can create new workload of a different type, which can be as demanding as that which is replaced (Bainbridge, 1983; Wiener, 1988). Automation usage can lead to unique problems with understanding the automation and force the operator to develop creative approaches for dealing with the automation – approaches that are seldom what the developer intended (Parasuraman & Riley, 1997; Sarter & Woods, 1995; Koopman & Hoffman, 2003).

In response to these challenges, researchers in the field have focused on automation reliability and trust (Lee & Moray, 1992; Riley, 1994), on determining appropriate levels of automation in order to avoid out-of-the-loop problems and to maintain operator SA (Endsley & Kaber, 1999; Endsley & Kiris, 1995; Kaber & Endsley, 1997; Parasuraman, Sheridan, & Wickens, 2000), and on approaches to adaptive automation that result in effective transfers of control between humans and automation (Kaber & Endsley, 2004; Kaber & Riley, 1999; Parasuraman, 1993; Scerbo, 1996). This broad corpus of work continues to expand as engineers develop different and more sophisticated forms of automation. These include decision support systems and intelligent agents of various kinds for a wide variety of domains, including medical systems, driving, aviation, and process control. Similar to work in the mental constructs area, most work on automation has featured experimentation in both field settings and simulations, although observations in domain settings have also been prominent.

Collaborative Work

A more recent focus in CEDM has been on the cognitive work of people in teams, either colocated or distributed, who must interact and collaborate to accomplish their tasks. Although there is a large body of research on teams similar to that on individuals, much of it is derived from laboratory studies with contrived tasks and teams of undergraduate students (McGrath, 1991). The focus on collaborative work in the CEDM field has been, rather, on how actual teams perform tasks in complex, real-world settings such as aviation, medicine, and command and control (Bolstad, Riley, Jones, & Endsley, 2002; Klein, Zsambok, & Thordsen, 1993; Orasanu, 1990; Salas, Dickinson, Converse, & Tannenbaum, 1992; Xiao, Mackenzie, & Patey, 1998). The processes and dynamics observed in these situations are often different from those observed in laboratory studies because of real-world circumstances and the expertise of the operators. This growing body of research clearly expands CEDM toward the development of training and technologies to support team collaboration (Bolstad & Endsley, 2005; Potter & Balthazard, 2002; Prince & Salas, 2000; Sonnenwald & Pierce, 2000). This work incorporates a wide variety of observational and experimental methods and actively contributes to the development of training programs as well as collaborative tools and shared displays for supporting shared situation awareness and team performance.

Summary

As we have shown, these various branches of the CEDM field come together and complement one another in often serendipitous ways. As the same phenomena are viewed through a multitude of perspectives, the results form a mosaic that can be pieced together to form a more complete guide for systems design and training applications than is possible through any single approach.

Future Directions

Although the foregoing account depicts the origin of CEDM and how it is practiced today, it is also worth discussing where the field should be headed in the future, given that a key goal for the *Journal of Cognitive Engineering and Decision Making* is to advance the science and its applications. First, though much of CEDM developed from dissatisfaction with the tools, concepts, and methods of previous engineering psychology and decision-making research, as well as the sterility of the psychology laboratory, it is not enough to be against something. To move forward as a field of research, CEDM must provide methods for analysis, design, and evaluation that provide guidance for improving human performance in these complex domains.

In many cases, the groundwork for these tools and methods is largely in place; there are a variety of cognitive task analysis and modeling methods, for instance, and experimental approaches and measures are widely available. In other areas the field needs to move forward. Defining what is acceptable for descriptive studies of cognitive phenomena is necessary, just as other areas of science (such as anthropology) have done for their fields.

Another major area for growth will be the need to more clearly delineate how to translate the many theories and findings of CEDM research into effective system designs for supporting these cognitive processes. If that translation remains largely subjective, varying from designer to designer and nongeneralizable from system to system, then we will have failed at our central mission. For CEDM to move forward as an effective force in system design, its theories and research must be specifiable into clearly articulated and repeatable design guidance. Likewise, there is a need to develop systematic approaches for translating static measures of learning and dynamic measures of performance that are generated by computational models into specific methods for determining usability in interface and system design.

It is also evident that the domains of CEDM practice have expanded over the past decade. Early concentrations featured work in aviation, air traffic control and process control, with more recent work also encompassing the medical field, command and control in both military and commercial applications, and unmanned vehicle control. This shift most likely represents a broadening of the domains that are seeking CEDM solutions rather than a shift in the domains that CEDM researchers think are important.

It is likely that the domains of interest will continue to grow and change in largely unpredictable ways. One of the great strengths of CEDM is its applicability across many seemingly disparate areas, from the control of unmanned aerial vehicles to diabetics' self-monitoring of glucose levels. A resultant opportunity is provided by this fact, as we will find new types of cognitive phenomena under new contexts and unique challenges that can be solved with CEDM approaches. It also allows for the exploration of the boundaries of our current methods and theories and provides an advantageous path for evolution and the bridging of gaps between the various communities of practice that make up CEDM.

Purpose and Scope of the Journal

It should be clear that CEDM is comprised of a mix of research approaches and contributions that are in some ways heterogeneous and at the same time reflect decades of cross influence. In some cases, researchers within communities of practice have come to recognize phenomena or issues that have been well known to practitioners in other communities. In other cases, seminal ideas from one community have been embraced by others. Thus, there has been significant cross-fertilization. As such, we are taking a "big tent" approach to the *Journal of Cognitive Engineering and Decision Making* in the belief that the science and the field will be best served by capturing the best of what these different approaches have to offer.

Because there is so much diversity, however, a one-size-fits-all approach to the review and evaluation of such work would be neither appropriate nor fruitful. Therefore, we have chosen to feature three different (although not completely independent) tracks in this journal as a means of facilitating the review process. This need not lead to confusion for CEDM researchers – manuscripts are submitted to the journal editor and then are directed to the appropriate track editor for evaluation and further action.

The first track, **Cognition in Context,** features work in the naturalistic and descriptive vein of CEDM, sometimes called *cognitive field research*. It covers papers that focus on describing the nature of work in various settings and the types of cognitive process that people employ "in the wild." The second track, **Studies in Simulations and Synthetic Environments,** features work that is typically of a more experimental nature, generally employing more manipulable high-fidelity representations of the task domain that allow for objective assessments of cognitive phenomena and technology and automation characteristics. The third track, **Design of Complex and Joint Cognitive Systems,** addresses the need for an outlet for very different types of papers that show how CEDM theories, principles, and research can be translated into training programs or workplace technologies that support individual and collaborative cognitive work. In all three tracks, research studies, theoretical papers, case studies, and methodological analyses are all appropriate contributions. We describe each track in more detail in the following sections.

Cognition in Context Track: Scope, Criteria, and Objectives

The Cognition in Context track features reports that represent advances in the science of cognition and macrocognitive phenomena in natural work environments. This includes naturalistic and ecological studies of domain-embedded knowledge and reasoning and may involve cognitive task analyses, cognitive work analyses, cognitive field research, or knowledge elicitation. Empirical studies are not constrained by method and can span the range of naturalism-experimentalism, including various kinds of interviews (ethnographic, sociological, and cognitive), experiment-like procedures conducted in field settings, observations of work patterns and workspaces, and attempts to "bring the world into the laboratory." Likewise, viewpoints or theoretical emphases are not constrained and can include cognitive views, computational ones, situated or distributed cognition views, or sociological, ethnographic, and anthropological views. As with the other tracks in *Journal of Cognitive Engineering and Decision Making*, we are interested in studies with important applications in areas such as human-centered computing.

Criteria include the dimensions listed in Table 1, especially ecological and epistemological utility, novelty, and generality. The track is especially suited for studies that advance the methodology of cognitive task analysis, including evaluations of research methods, comparisons of methods, the development of new methods, and the general exploration of methodological issues and issues of measuring cognitive work.

Priority will be given to papers that are salient for the CEDM community in that they represent a contribution to theory or methods beyond what is already known in such fields as human factors, naturalistic decision making, cognitive systems engineering, and the sociology of the professions. Ideally, papers are desired that are salient for the domains of practice that are studied in the research. Thus, this track focuses on studies that include analyses of many domains of cognitive work and that rely on the participation of domain practitioners.

Studies in Simulations and Synthetic Environments Track: Scope, Criteria, and Objectives

The focus of this track is on the discovery and description of cognitive processes and constructs, information processing theories and methods (as well as alternate viewpoints and theories), and an assessment of the implications of technology

TABLE 1. Dimensions that typify CEDM research (after Hoffman & Deffenbacher, 1993)

The Relation of Methods to the Ecology of Cognitive Work	
Ecological validity	Materials, tasks, and settings present events in a way that preserves their natural forms and the natural covariation of dimensions or cues.
Ecological relevance	Materials or tasks involve things that people actually perceive or do.
Ecological salience	Materials or tasks involve important things that people actually perceive or do.
Ecological representativeness	Materials or tasks involve things that people often perceive or do.
The Relation of Methods to Scientific Understanding	
Epistemological validity	Materials and tasks make sense in terms of available theories and accepted methodologies
Epistemological relevance	Materials and tasks link to current theoretical or methodological issues.
Epistemological salience	Materials and tasks link to theoretical concepts or research issues that are generally regarded as important.
Epistemological representativeness	Materials and tasks rely on theoretical and methodological concepts on which scientists often rely.
The Relation of Results to Action	
Ecological utility	The results help you do important things.
Ecological novelty	The results help you do new things.
Ecological generality	The results help you do things in diverse contexts.
The Relation of Results to Scientific Understanding	
Epistemological utility	The results lead to refinements in hypotheses and theories.
Epistemological novelty	The results suggest new theoretical concepts or hypothetical mechanisms.
Epistemological generality	The results have implications for diverse theories or hypotheses.

characteristics on human performance through the use of cognitively rich simulations involving individual experts or teams. Reports of research with computer-based simulations or Internet-based simulation studies are also sought.

Historically, human factors research has focused on perceptual and psychomotor aspects of information processing as a basis for guiding human-machine interaction and systems design (e.g., Sanders & McCormick, 1993). This was partly attributable to a lack of sensitive and reliable measures for assessing more imbedded cognitive constructs and the difficulty of relating results to performance and design decisions. Systematic approaches to design that integrated the knowledge of engineering psychology with concepts of automation, such as supervisory control (Sheridan, 1992), were developed, resulting in many general guidelines for human-machine interface features for practitioner use. Although this work forms an important foundation for the human factors discipline, there remains a need for experimental and modeling work in CEDM that addresses the challenges of complex systems and cognitive work. This research should provide a basis for design guidelines rooted in explanations of why cognitive behaviors occur and in some cases cause errors or performance decrements in complex systems control. A deeper understanding of cognitive processes in human-automation interaction under critical conditions can lead directly to design decisions that support cognitive performance.

The aim of the Studies in Simulations and Synthetic Environments track is to showcase empirical and modeling research that provides a basis for systems engineering and design by elucidating cognitive phenomenon under critical task circumstances. This type of research typically requires realistic simulations of actual task environments that allow a high degree of control over independent variables and the use of advanced cognitive and information-processing models for the specification of hypotheses on mental constructs and for testing. This track provides a forum for research that is relevant to all aspects of cognition and the use and development of advanced simulation tools (e.g., virtual reality) for assessment. It is a forum for presenting to the human factors community new CEDM research tools, new CEDM methods for empirical research, designs of interactive simulation systems, results from field and lab studies involving simulations and task experts, and descriptions of new mental construct theories based on simulation research.

Relevant topic areas include the following:

1. Design and development of simulation platforms and synthetic environments for studying contemporary CEDM domains, including health care, medical systems, and human-robot interaction (e.g., unmanned-vehicle control).
2. Design and validation of generalizable PC-based or Internet simulations (e.g., high-fidelity flight simulations, PC-based human-in-the-loop simulations) for CEDM research and evaluation of specific interface interaction techniques.
3. Adaptation of existing CEDM research methods, including measures of cognitive workload (e.g., EEG indices of engagement) and situation awareness (e.g., probes and testable responses), for use in synthetic environments and real working environments through validation using simulation.

4. Development and demonstrations of cognitive models (e.g., GOMSL, ACT-R, SOAR, IMPRINT) for explaining and predicting task expert performance in complex systems controls under nominal and hazardous states of awareness.
5. Development of new approaches for systematically translating the results of cognitive model applications to guidelines for systems interface design to support operator SA and workload management.
6. Use of cognitive models in conjunction with synthetic environments for evaluating explicit theories on mental constructs and complex task performance strategies involving human interaction with decision support systems or intelligent agents.

The review of papers submitted to this *JCEDM* track includes a consideration of the following criteria:

- Papers must fit the types of research considered by the Studies in Simulations and Synthetic Environments track.
- Papers must specifically address the success or failure of an approach and provide explanations.
- Papers must make clear the new insight provided into one of the areas of CEDM research and how its results compare with previous research, as well as any broader impact for advancing CEDM practice.
- Papers must provide a validation section on any new methods or an example of the application of new theories.

Beyond these criteria, papers must provide a clear rationale for design decisions, and the stages of the design process must flow logically. The outcomes of the research must be directly linked to specific CEDM research needs. The manuscript must demonstrate how any new simulation or synthetic environment will advance CEDM research.

For empirical studies, papers must present a concise set of hypotheses that motivate the specific experimental manipulations in a simulation. Results of the experiment must be linked back to the hypotheses through concise discussion. Theory and research modeling manuscripts must summarize a corpus of simulation or synthetic environment-based studies in an area of CEDM research that supports the new general theory. That is, all theories must be given a pedigree in existing related CEDM theories. Manuscripts of this nature must also provide at least one detailed example of how the new theory may serve to identify underlying factors in CEDM research problems or explain human information processing in the context of interaction with complex systems.

The electronic or online companion (described later) can also be used as a resource by authors who submit their work to the Studies in Simulations and Synthetic Environments track, particularly for presenting dynamic content, such as videos of simulations used in experiments. As for the Design of Complex and Joint Cognitive

Systems track, we encourage potential authors to consider the use of the electronic companion to *JCEDM*.

Design of Complex and Joint Cognitive Systems Track: Scope, Criteria, and Objectives

The Design of Complex and Joint Cognitive Systems track focuses on the process and product of innovative design. This includes the design of training and support systems for individuals and teams working with complex sociotechnical systems. Much research in CEDM has traditionally addressed the analysis of cognitive systems in context. It relies on a rich set of analysis tools that yield powerful insights into how individuals and teams make decisions in naturalistic situations and the contextual factors and constraints that shape performance. However, the process of drawing design implications from analyses of naturalistic decision making in context remains largely an art. Although there have been some advances in developing methods and tools for deriving principled design guidance, there is often a significant gap with regard to how to convert the results of contextual analyses into specific implications for design of innovative systems that more effectively support performance (Potter, Elm, Roth, Gualtieri, & Easter, 2002; Wampler et al., 2006).

The Design of Complex and Joint Cognitive Systems track aims to showcase research targeted at bridging the gap between analysis and design. The track encompasses research papers that are broadly relevant to the design of innovative systems. It provides a vehicle for presenting creative design research that has not traditionally had outlets within the human factors and related communities, as well as theoretical and methodological papers aimed at advancing the theory and practice of design.

Relevant topic areas include the following:

1. Theories, methods, and studies of design that contribute to our understanding of how to design systems that more effectively foster cognitive and collaborative work of individuals, teams, and organizations. Studies might involve evaluations of systems or envisioning exercises and empirical analyses that capture critical information about the impact of system designs on cognition and collaboration.
2. Innovative design concepts and their theoretical rationale. The goal is to describe the design concepts, support rationale, and design principles they embody. Formal evaluation studies of the design concepts are not required, but papers need to present clear, persuasive evidence of the effectiveness of the design in the domain of application and the generality of the design or design principles embodied in the design, beyond the particular application.
3. Theories, methods, and case studies addressing the role of CEDM in the wider systems design enterprise. This includes papers that examine the role of analysis, envisioning, and evaluation within the broader context of design and engineering of large, complex systems.
4. Theoretical perspectives that stimulate dialogue on important topics in the theory or practice of design. This includes literature synthesis papers that pre-

sent a particular perspective on the theory or practice of design. Papers that can provide a focal point for additional shorter commentary papers reflecting alternative perspectives on the core theme are particularly appropriate for the track.

Evaluation criteria for papers submitted to the design track will necessarily differ from evaluation criteria traditionally used in the human factors field to evaluate research using conventional experimental design methods. Criteria for evaluating design papers include the originality of the presented concepts, how well argued and rigorously supported are the claims made, and how significant the contribution is to CEDM theory and practice (see also Table 1). In the case of papers that present innovative designs, additional evaluation criteria are reflected in these questions:

- Are the proposed design concepts grounded in an analysis of the domain and work context?
- Is persuasive evidence provided for the effectiveness of the design? (This can include laboratory or field study results.)
- Are the results generalizable beyond the specific application?
- (In the case of new methods, models, or tools for design) How innovative is the approach? What evidence is provided that the method contributes to successful design? (This can include presentation of illustrative case studies of its application or formal evaluations.)
- (In the case of papers that present literature syntheses and new theory) Does it address an important gap in the theory or practice of design? Is it likely to stimulate dialogue among research and practitioners so as to advance the state of the art?

A final point to highlight is the availability of a companion online forum for *Journal of Cognitive Engineering and Decision Making* readers (see the next section). This electronic resource is particularly attractive for communicating aspects of innovative design research that are not well captured by traditional media. Authors can include links to companion electronic media to provide dynamic depictions of design concepts, video clips of user interactions that motivated the design, or video clips that depict use of the design in context. We strongly encourage authors to take advantage of this powerful multimedia communication resource.

JCEDM Online Forum

In addition to a regular journal format, we envision a broader approach that takes advantage of the new capabilities provided by the Internet. The accelerating pace of development and evolution in electronic publishing, including the increased rate of citation of electronic venues, seems to include ample evidence of the utility of the new format for scientists. In this vein, we are providing an online forum for *JCEDM*. This Internet companion is intended to spur the growth of the CEDM field and to serve the needs of researchers and practitioners.

To take advantage of this tool, go to *http://cedm.webexone.com*. Click on the link to enter as a guest. On this site you will find

- traditional and electronic contact information for authors;
- links to the online version of the journal for viewing by those who subscribe to the online version, or for direct purchasing of articles;
- links to online resources (e.g., Web sites) associated with material discussed in an article, as provided by the authors;
- an index of *JCEDM* articles
- online discussions and debates concerning the articles in the journal or topics of interest in the field;
- calendars of conferences and events of interest to CEDM researchers and practitioners;
- databases for sharing documents or other information amongst participants (e.g., bibliographies or cognitive task analyses)
- links to universities and organizations that practice CEDM.

This unique feature allows the Web site and *JCEDM* to jointly serve as a central hub for researchers in this field. It is up to those within CEDM to supply the content and energies that will make it successful. It is a movable landscape and one that will adapt as the field changes and grows.

What's Next?

We invite you to enjoy this inaugural issue of the *Journal of Cognitive Engineering and Decision Making*. We want you to make this journal *your* journal. Information on subscribing to *JCEDM* and on submitting manuscripts for publication is provided inside the printed issue (or at *http://www.hfes.org/Publications/ProductDetail.aspx?ProductID=64*). If you have ideas or recommendations for *JCEDM,* please contact us by e-mail or through the online companion Web site, *http://cedm.webexone.com*. As editors of the journal, we stand ready, along with the *JCEDM* online forum, for your contributions to the CEDM field.

Acknowledgments

The contribution of the first two authors was made possible partly through participation in the Advanced Decision Architectures Collaborative Technology Alliance, sponsored by the U.S. Army Research Laboratory under Cooperative Agreement DAAD19-01-2-0009.

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