Cognitive Systems Engineering

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What is cognitive systems engineering?

Cognitive systems engineering is a specialty discipline of systems development that addresses the design of socio-technical systems. A sociotechnical system is one in which humans provide essential functionality related to deciding, planning, collaborating and managing. Drawing on contemporary insights from cognitive, social and organizational psychology, cognitive systems engineers seeks to design systems that are effective and robust. The focus is on amplifying the human capability to perform cognitive work by integrating technical functions with the human cognitive processes they need to support and on making that cognitive work more reliable.

Cognitive systems engineers assist with the design of human interfaces, communication systems, training systems, teams, and management systems. They employ principles and methods that bear on the design of procedures, processes, training and technology. Examples of systems that can benefit are military command and control, civil air traffic control, transportation, communication, process control, power generation, power distribution, health-care, and large-scale project infrastructure.

What is the added value?

What is the added value for anything? If you add insulation or double-glazed windows to your home to save energy costs, you can calculate the costs and estimate the savings. That is straightforward enough. Large-scale engineering projects are not as straightforward. To assess the added value of cognitive systems engineering to large-scale engineering projects, we would have to track and compare projects that used no cognitive systems engineering versus those that used a minimal amount versus those that used a decent amount, and even then, we would have to assess the quality of the cognitive systems engineering that was used. These sorts of data are not available anywhere.

We could turn to accident reports that recount the enormous losses incurred within socio-technical systems by breakdowns in decision making, planning, communication and information sharing. As I prepare this paper, the huge financial and social costs associated with the April, 2010 oil spill from Deep Water Horizon in the Gulf of Mexico may be fading from public awareness only to be replaced by those of the March, 2011 Fukushima nuclear power crisis. There is, however, little to be learned from a seemingly endless parade of the frailties of poorly-managed socio-technical systems except possibly to reinforce what we already know; that humans do not function well in systems that are poorly designed and poorly managed.

In contrast, there are powerful lessons to be learned from positive illustrations.

- The safety of commercial aviation has been enhanced enormously by the use of cockpit resource management (Helmreich & Wilhelm, 1991) and by development of the Aviation Safety Reporting System (Reynard, Billings, Cheaney & Hardy, 1986).
- During the early years of the current NATO led conflict in Afghanistan, knowledge management within the US 5th Fleet was transformed by the development of a community-based knowledge web that supported mission analysis, mission planning and operational briefing (Adkins & Kruse, 2003).
- An investment of approximately US$38 million in an advanced landmine detector, which exhibited detection rates for plastic mines at a dismal 5%, was saved by a cognitively-inspired training program, which took detection rates up to 95% (Staszewski, 2004).
- Cognitive redesign transformed an emergency management team at a nuclear power station from one that was regularly downgraded during annual evaluations to one that passed with flying colors (Klinger & Klein, 1999).

All of these successes were driven by principles from cognitive systems engineering. In all of these examples, the cost of analysis, design and implementation was trivial in relation to the potential costs associated with leaving those systems as they were.

What is the role for cognitive systems engineering?

The need for a systematic and comprehensive approach to cognitive issues in the design of sociotechnical systems has emerged over the past 20 years as computer-based technologies have pushed the nature of operational work in a direction in which cognitive challenges dominate. Issues such as decision-making in complex and dynamic information environments, distributed collaboration, and management of extensively networked systems have, in many cases, transformed the nature of work. Cognitive systems engineers identify the cognitive states, the cognitive processes, and the cognitive strategies used by skilled practitioners to perform this work and subsequently develop design solutions for such things as decision and planning tools that support expert human cognition.

At an abstract level of description, the approach taken is straightforward and not all that different to the analysis and design strategies used in other areas of engineering. Cognitive systems engineers observe the field practice and represent the knowledge thus acquired in some form that facilitates the design of appropriate cognitive support systems. Those design solutions are then evaluated via computer modelling or human-in-the-loop simulation. While this approach will sound familiar to many engineers, the tools used for knowledge acquisition, knowledge representation and cognitive modelling will not. These have been developed specifically to deal with the complex and nonlinear nature of human cognition; its hidden interdependencies and those of its processes that are beyond the conscious awareness of the operational expert.

Within the development of any large-scale, sociotechnical system, cognitive systems engineering has important roles to play throughout the acquisition life cycle. It has tools and strategies that can be used to identify human-relevant operational requirements and operational demands, to generate human-compatible solution descriptions, and to design cognitive support systems. Finally, it has tools for verifying and validating cognitive performance and for monitoring and enhancing system safety performance.

Summary

In this brief introduction, I have described what cognitive systems engineering is, how it is useful, and why it is of value. Cognitive systems engineering grapples with issues that are generally handled poorly in systems design and systems acquisition.

Human cognition is one crucial dimension on which sociotechnical systems can fail, often with disastrous consequences. On the other hand, it is also a dimension that can transform the overall performance of a sociotechnical system. In particular, cognitive systems engineers do not treat the human as a user or operator but rather as an entity with functional properties that contribute to system performance. Physical engineers understand that they must take special care at the seam between materials having different properties. And so it is with cognitive systems engineering. The properties of the human cognitive system are unlike those of the technological sub-systems. Special care is needed to integrate these different kinds of functional entities.

If you want to know more, I invite you to write to me for papers on the relationship between Cognitive Systems Engineering and Systems Engineering or for my flash video, *Cognitive Systems Engineering for Systems Engineering.*

References

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