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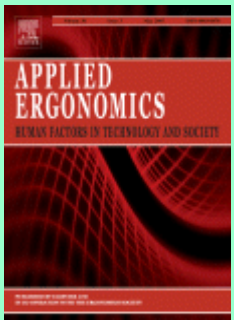

Patrick Waterson, Daniel P. Jenkins, Paul M. Salmon, Peter Underwood. *'Remixing Rasmussen': The evolution of Accimaps within systemic accident analysis*. Pages 483-503.

Throughout Jens Rasmussen's career there has been a continued emphasis on the development of methods, techniques and tools for accident analysis and investigation. In this paper we focus on the evolution and development of one specific example, namely Accimaps and their use for accident analysis. We describe the origins of Accimaps followed by a review of 27 studies which have applied and adapted Accimaps over the period 2000–2015 to a range of domains and types of accident. Aside from demonstrating the versatility and popularity of the method, part of the motivation for the review of the use of Accimaps is to address the question of what constitutes a sound, usable, valid and reliable approach to systemic accident analysis. The findings from the review demonstrate continuity with the work carried out by Rasmussen, as well as significant variation (e.g., changes to the Accimap, used of additional theoretical and practice-oriented perspectives on safety). We conclude the paper with some speculations regarding future extension and adaptation of the Accimap approach including the possibility of using hybrid models for accident analysis.

- **Keywords:** Accident analysis and investigation; Sociotechnical systems; Accimaps; Organisational design; Jens Rasmussen

Dohyung Kee, Gyuchan Thomas Jun, Patrick Waterson, Roger Haslam. *A systemic analysis of South Korea Sewol ferry accident: Striking a balance between learning and accountability*. Pages 504-516.

The South Korea Sewol ferry accident in April 2014 claimed the lives of over 300 passengers and led to criminal charges of 399 personnel concerned including imprisonment of 154 of them as of Oct 2014. Blame and punishment culture can be prevalent in a more hierarchical society like South Korea as shown in the aftermath of this disaster. This study aims to analyse the South Korea ferry accident using Rasmussen's risk management framework and the associated AcciMap technique and to propose recommendations drawn from an AcciMap-based focus group with systems safety experts. The data for the accident analysis were collected mainly from an interim investigation report by the Board of Audit and Inspection of Korea and major South Korean and foreign newspapers. The analysis showed that the accident was attributed to many contributing factors arising from front-line operators, management, regulators and government. It also showed how the multiple factors including economic, social and

political pressures and individual workload contributed to the accident and how they affected each other. This AcciMap was presented to 27 safety researchers and experts at 'the legacy of Jens Rasmussen' symposium adjunct to ODAM2014. Their recommendations were captured through a focus group. The four main recommendations include forgive (no blame and punishment on individuals), analyse (socio-technical system-based), learn (from why things do not go wrong) and change (bottom-up safety culture and safety system management). The findings offer important insights into how this type of accident should be understood, analysed and the subsequent response.

- **Keywords:** Sociotechnical systems; Systems safety; Accident investigation; AcciMap; Jens Rasmussen

Samuel Lee, Young Bo Moh, Maryam Tabibzadeh, Najmedin Meshkati. *Applying the AcciMap methodology to investigate the tragic Sewol Ferry accident in South Korea*. Pages 517-525.

This study applies the AcciMap methodology, which was originally proposed by Professor Jens Rasmussen (1997), to the analysis of the tragic Sewol Ferry accident in South Korea on April 16, 2014, which killed 304 mostly young people and is considered as a national disaster in that country. This graphical representation, by incorporating associated socio-technical factors into an integrated framework, provides a big-picture to illustrate the context in which an accident occurred as well as the interactions between different levels of the studied system that resulted in that event. In general, analysis of past accidents within the stated framework can define the patterns of hazards within an industrial sector. Such analysis can lead to the definition of preconditions for safe operations, which is a main focus of proactive risk management systems. In the case of the Sewol Ferry accident, a lot of the blame has been placed on the Sewol's captain and its crewmembers. However, according to this study, which relied on analyzing all available sources published in English and Korean, the disaster is the result of a series of lapses and disregards for safety across different levels of government and regulatory bodies, Chonghaejin Company, and the Sewol's crewmembers. The primary layers of the AcciMap framework, which include the political environment and non-proactive governmental body; inadequate regulations and their lax oversight and enforcement; poor safety culture; inconsideration of human factors issues; and lack of and/or outdated standard operating and emergency procedures were not only limited to the maritime industry in South Korea, and the Sewol Ferry accident, but they could also subject any safety-sensitive industry anywhere in the world.

- **Keywords:** AcciMap; Sewol Ferry accident; South Korea; Complex systems; Safety culture; Human factors; Accident investigation; Jens Rasmussen

Neelam Naikar. *Cognitive work analysis: An influential legacy extending beyond human factors and engineering*. Pages 528-540.

Jens Rasmussen's multifaceted legacy includes cognitive work analysis (CWA), a framework for the analysis, design, and evaluation of complex sociotechnical systems. After considering the framework's origins, this paper reviews its progress, predictably covering experimental research on ecological interface design, case studies of the application of CWA to human factors and engineering problems in industry, and methods and modelling tools for CWA. Emphasis is placed, however, on studying the nexus between some of the recent results obtained with CWA and the original field studies of human problem-solving that motivated the framework's development. Of particular interest is a case study of the use of CWA for military doctrine development, a problem commonly regarded as lying outside the fields of human factors and engineering. It is concluded that the value of CWA, even for such diverse problems, is likely to result from its conceptual grounding in empirical observations of patterns of human reasoning in complex systems.

- **Keywords:** Cognitive work analysis; Problem-solving; Reasoning; Sociotechnical systems; Jens Rasmussen

William B. Rouse, Michael J. Pennock, Mehrnoosh Oghbaie, Chen Liu. *Interactive visualizations for decision support: Application of Rasmussen's abstraction-aggregation hierarchy*. Pages 541-553.

Data visualization has of late received an enormous amount of attention from both researchers and practitioners. Even the popular press often includes impressive visualizations of various data sets. Interactive visualizations frequently include data visualizations, but they differ in that users employ the visualizations to make inferences, reach conclusions, and make decisions that result in changed and/or new visualizations. Data visualizations emphasize "what is," but interactive visualizations address "what if." In this way, interactive visualizations are often intended for decision support. This article addresses the design of interactive visualizations for decision support. An overall methodology is presented; central to this methodology is Jens Rasmussen's abstraction-aggregation hierarchy. The results of two applications and evaluations of the outcomes of using this methodology are discussed. The first application focused on interactive visualizations for helicopter maintenance. The second application addressed "enterprise diagnostics" in the automobile industry where subjects were asked to diagnose the cause of failed automobile brands. The results of these two applications are used to assess the efficacy of the proposed methodology.

- **Keywords:** Interactive visualizations; Abstraction-aggregation hierarchy; Maintenance; Enterprise diagnostics

Sidney W.A. Dekker. *Rasmussen's legacy and the long arm of rational choice*. Pages 554-557.

Rational choice theory says that operators and others make decisions by systematically and consciously weighing all possible outcomes along all relevant criteria. This paper first traces the long historical arm of rational choice thinking in the West to Judeo-Christian thinking, Calvin and Weber. It then presents a case study that illustrates the consequences of the ethic of rational choice and individual responsibility. It subsequently examines and contextualizes Rasmussen's legacy of pushing back against the long historical arm of rational choice, showing that bad outcomes are not the result of human immoral choice, but the product of normal interactions between people and systems. If we don't understand why people did what they did, Rasmussen suggested, it is not because people behaved inexplicably, but because we took the wrong perspective.

- **Keywords:** Rasmussen; Rational choice; Human error; Second victim; Incidents

Jean-Christophe Le Coze. *Reflecting on Jens Rasmussen's legacy (2) behind and beyond, a 'constructivist turn'*. Pages 558-569.

This article is the second part of a study on the legacy of Jens Rasmussen. The first article, subtitled 'A Strong Program for a Hard Problem', looks back on his 30 years of scientific contribution, from 1969 to 2000. This second article explores and investigates some of the intellectual roots which influenced his thinking, using them as a basis to understand some limits and move forward. Indeed, historically oriented studies such as this one are not only tributes to researchers, but a way to differentiate and contrast our present situation with the past in order to integrate contemporary trends, be they theoretical or empirical, or oriented towards research and new models. In the first section of this article, I offer a synthesis of the background covered in the previous article, but I use a tree here as a graphical complement. Branches of the tree show the many fruitful directions opened by Jens Rasmussen, directions which inspired many researchers. In the second part, I address what I believe to be behind this wealth of

engineering legacy: cybernetics. I contend that cybernetics has had a profound influence on his thinking and provided him key principles for his inspiring and successful models. To develop the tree image, one might say that cybernetics is the trunk of the tree. Finally, in the third part, I take the opportunity to explore the relevance of extending and sensitising his program to constructivist discourses. After an introduction to this discourse, identifying four types of constructivisms (cognitive, social, epistemological and anthropological), I characterise this move as a 'constructivist turn'.

- **Keywords:** Rasmussen; Constructivism; Safety; Sociotechnical systems; Model

Vivek Kant. *Supporting the human life-raft in confronting the juggernaut of technology: Jens Rasmussen, 1961–1986*. Pages 570-580.

Jens Rasmussen's contribution to the field of human factors and ergonomics has had a lasting impact. Six prominent interrelated themes can be extracted from his research between 1961 and 1986. These themes form the basis of an engineering epistemology which is best manifested by his abstraction hierarchy. Further, Rasmussen reformulated technical reliability using systems language to enable a proper human-machine fit. To understand the concept of human-machine fit, he included the operator as a central component in the system to enhance system safety. This change resulted in the application of a qualitative and categorical approach for human-machine interaction design. Finally, Rasmussen's insistence on a working philosophy of systems design as being a joint responsibility of operators and designers provided the basis for averting errors and ensuring safe and correct system functioning.

- **Keywords:** Jens Rasmussen; Engineering epistemology

Nancy G. Leveson. *Rasmussen's legacy: A paradigm change in engineering for safety*. Pages 581-591.

This paper describes three applications of Rasmussen's idea to systems engineering practice. The first is the application of the abstraction hierarchy to engineering specifications, particularly requirements specification. The second is the use of Rasmussen's ideas in safety modeling and analysis to create a new, more powerful type of accident causation model that extends traditional models to better handle human-operated, software-intensive, sociotechnical systems. Because this new model has a formal, mathematical foundation built on systems theory (as was Rasmussen's original model), new modeling and analysis tools become possible. The third application is to engineering hazard analysis. Engineers have traditionally either omitted human from consideration in system hazard analysis or have treated them rather superficially, for example, that they behave randomly. Applying Rasmussen's model of human error to a powerful new hazard analysis technique allows human behavior to be included in engineering hazard analysis.

- **Keywords:** Rasmussen; Systems theory; STAMP; Intent specifications

Robert L. Wears. *Rasmussen number greater than one*. Pages 592-597.

This essay describes the ramifying influence of Jens Rasmussen, illustrating how his work lives on through people whom he has influenced, even though they may have never directly collaborated. I approach this in three ways: a social network analysis of the 'Rasmussen number' (an analogue of the Erdös number); and two citations network analyses based on different search domains and different network structures.

- **Keywords:** Social networks; Citation networks

Thomas B. Sheridan. *Musings on Models and the Genius of Jens Rasmussen*. Pages 598-601.

Two well-known Rasmussen models, the skill-rule knowledge (SRK) paradigm and the abstraction hierarchy, are compared to well-known models in both physics and psychology. Some of the latter are quantitative and make explicit predictions; some are qualitative, such as the Rasmussen models, being more useful for provoking thought about the relevant issues. Each of the Rasmussen models is evaluated with respect to six-attribute model taxonomy recently introduced by the author. The SRK model is shown to characterize modern automation as well as human behavior, with computer and physical devices exhibiting the a skill-based, rule-based and knowledge-based properties, and with monitoring and intermittent intervention by a human supervisor. A further suggestion is that the Rasmussen abstraction hierarchy could be applied not only to systems such as air traffic control but also to general situations of living.

Antony Hilliard, Greg A. Jamieson. *Representing energy efficiency diagnosis strategies in cognitive work analysis*. Pages 602-611.

This article describes challenges encountered in applying Jens Rasmussen's Cognitive Work Analysis (CWA) framework to the practice of energy efficiency Monitoring & Targeting (M&T). Eight theoretic issues encountered in the analysis are described with respect to Rasmussen's work and the modeling solutions we adopted. We grappled with how to usefully apply Work Domain Analysis (WDA) to analyze categories of domains with secondary purposes and no ideal grain of decomposition. This difficulty encouraged us to pursue Control Task (ConTA) and Strategies (StrA) analysis, which are under-explored as bases for interface design. In ConTA we found M&T was best represented by two interlinked work functions; one controlling energy, the other maintaining knowledge representations. From StrA, we identified a popular representation-dependent strategy and inferred information required to diagnose faults in system performance and knowledge representation. This article presents and discusses excerpts from our analysis, and outlines their application to diagnosis support tools.

- **Keywords:** Systems; Engineering; Cognitive; Work analysis; CWA; Ecological interface design; EID; Energy; Monitoring and targeting; M&T; Strategies; Diagnosis

John Flach. *Supporting productive thinking: The semiotic context for Cognitive Systems Engineering (CSE)*. Pages 612-624.

The central thesis of this paper is that Rasmussen framed his approach to Cognitive Systems Engineering from the perspective of a Triadic Semiotic Model. This frame became the context for integrating multiple intellectual threads including Control Theory, Information Theory, Ecological Psychology, and Gestalt Psychology into a coherent theoretical framework. The case is made that the triadic semiotic framework is essential for a complete appreciation of the constructs that were central to Rasmussen's approach: Abstraction Hierarchy, Skill-Rules-Knowledge Model, Ecological Interface Design, and Proactive Risk Management.

- **Keywords:** Cognitive Systems Engineering; Abstraction Hierarchy; Work domain analysis; Decision Ladder; Skills-Rules-Knowledge Model; Ecological Interface Design; Proactive Risk Management

Kevin B. Bennett. *Ecological interface design and system safety: One facet of Rasmussen's legacy*. Pages 625-636.

The focus of this manuscript is on cognitive systems engineering/ecological interface design (CSE/EID) and the role that this framework may play in improving system safety. First, the decision making and problem solving literatures are reviewed with an eye towards informational needs that are required to support these activities. The utility of two of Rasmussen's analytical tools (i.e., the abstraction and aggregation hierarchies) in conducting work domain analyses to identify associated information (i.e., categories and relationships) is discussed. The importance of designing ecological displays and interfaces that span the informational categories in the abstraction hierarchy is described and concrete examples are provided. The potential role that ecological interfaces can play in providing effective decision making (i.e., preventing accidents) and problem solving (i.e., dealing with accidents) support, thereby improving the safety of our socio-technical systems, is explored.

- **Keywords:** Safety; Ecological interface design; Work domain analysis

Paul M. Salmon, Natassia Goode, Natalie Taylor, Michael G. Lenné, Clare E. Dallat, Caroline F. Finch. *Rasmussen's legacy in the great outdoors: A new incident reporting and learning system for led outdoor activities*. Pages 637-648.

Jens Rasmussen's seminal risk management framework and accompanying Accimap method have become highly popular in safety science circles. Despite this, widespread adoption of the model and method in practice has not yet been achieved. This paper describes a project involving the development and implementation of an incident reporting and learning system underpinned by Rasmussen's risk management framework and Accimap method. The system was developed for the led outdoor activity sector in Australia to enable reporting and analysis of injuries and near miss incidents, with the aim of supporting the development of more effective countermeasures. An analysis of the data derived from the first 3 months use of the system by 43 organisations is presented. The outputs provide an in-depth Accimap-based analysis of all incidents reported by participating organisations over the 3 month period. In closing, the importance of developing usable domain specific tools to support translation of Ergonomics theory and methods in practice is discussed.

- **Keywords:** Incident reporting systems; Rasmussen; Accimap; Accident analysis; Injury

Penelope Sanderson, Catherine Burns. *Rasmussen and the boundaries of empirical evaluation*. Pages 649-656.

In this special issue, many of the papers focus on Rasmussen's analytic contributions to the understanding of work in complex sociotechnical systems. Work is analysed for the purpose of developing new designs that can improve the nature of that work. The evaluation of such designs was a key part of Rasmussen's program, yet he was often sceptical of the claims made for the generalizability of empirical studies. To tackle this problem, he extended his work analysis framework to provide a way of thinking about empirical evaluation. As authors of this paper, we come from two different backgrounds—systems engineering in the case of Burns, and engineering psychology in the case of Sanderson—and over the decades of our respective research programs, we have both performed many empirical investigations: field investigations, simulation studies, and behavioural laboratory experiments. Rasmussen's scepticism—and his writings on the issue—have stimulated and shaped our own research. In this brief paper we present our interpretation of Rasmussen's perspective, we provide examples how our research sits within Rasmussen's framework of constraints defining boundary conditions for experiments, and we draw conclusions for the future.

- **Keywords:** Jens Rasmussen; Empirical evaluation; Constraints; Work analysis