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Supporting the human life-raft in confronting the juggernaut of technology: Jens Rasmussen, 1961–1986

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ABSTRACT

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.

> "It is probably not far from the truth to say that it will always be so - matters relating to an optimal incorporation of humans into systems can be likened to a little life-raft struggling to keep afloat in the wake of the juggernaut of technology - but never catching up. Therefore, any attempts to at least minimize the effects of this unfortunate state of affairs must be based on generalizable concepts and theories which can readily be adapted to a changing world" (Goodstein and Rasmussen, 1980d, p. 41)

1. Introduction

Jens Rasmussen is an innovator in the fields of Safety Science and Human Factors and Ergonomics (HFE). His groundbreaking theoretical approach asserts a lasting impact on fundamental issues related to the above two fields. During the years 1961–1986, Rasmussen provided a fundamental understanding for cognitive modeling and interface design for human-machine interaction. This paper presents a thematic survey of his English language papers (and Risø work reports) between 1961 and 1986, with a special emphasis on the dimension of engineering epistemology in his approach. The themes that Rasmussen addressed are still pertinent to the field of HFE and can be used to provide novel extensions. For example, the themes identified in this article have been used to extend Cognitive Work Analysis (CWA, Vicente, 1999). Based on these themes, CWA was extended at a fundamental level in terms of accounting for the body and socio-cultural dimension of human knowing and acting for gathering requirements for interface design (see Kant, 2015; Chs. 2, 4, 5 for details).

Returning to Rasmussen's original ideas also allows the modern engineer to grasp the manner in which he formulated the problem and devised a solution in an intellectually singular manner. Especially noteworthy is that he produced an engineering solution to the problem of technical systems reliability. Even though he addressed issues related to human knowing and acting, in his papers he repeatedly emphasized that his approach is not an application of psychological science but is an engineering approach (c.f. Woods and Roth, 1988; Wilson et al., 2013). This aspect of Rasmussen's approach is crucial as it allows for a different way of thinking about cognitive engineering and related engineering fundamentals (see Vicente, 1998 for Risø genotype). In this paper, Rasmussen's approach as a contribution to engineering epistemology has been briefly addressed and can be found in a detailed discussion and chronological survey in Kant, 2015 (Appendix A, also see Kant, 2015; Ch. 3 for a discussion of engineering epistemology).

During the years 1961–1986 six main interrelated themes are

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salient in Rasmussen's approach. First, Rasmussen presents an engineering knowledge structure that is not a mere application of knowledge gained from psychological science (cognitive science). Treatment of the problem in engineering terms involves not only considering design but also verification and evaluation from a conceptual, qualitative perspective. Second, Rasmussen treats the problem as a holistic systems design problem rather than a divide-and-conquer reductive approach. Therefore, the proposed knowledge framework has elements that fit seamlessly together and have a common underlying understanding of the human and the work environment. Third, he addresses the human as a part of the system and provides a conceptualization of the human in the language of engineering. In doing so, he does not reduce the human to a mechanism, but forms a conceptualization that takes into account the various dimensions required for understanding the human in the overall system functioning. Fourth, Rasmussen emphasizes the need to design for and support the everyday knowing and acting of the operator. This includes understanding the human's (operator's) viewpoint and subjectivity; supporting their common sense reasoning; as well as acknowledging and designing for their tacit knowing and "process feel". As a result, the emphasis is on a qualitative and categorical mode of enquiry. Finally, an important theme in Rasmussen is the intertwined roles of the operator and designer for successful systems design. The designer and operator are together involved in the design of the control system based on a working philosophy of shared responsibility.

The current article is divided into four main sections. Section 2 provides a background of the past historical research conducted on Rasmussen's approach. Section 3 provides the details of the methodology adopted in this paper and delineates the scope of this article. Section 4 presents the results in the form of six major themes found in Rasmussen's approach. Finally, the article concludes with directions for further research (Section 5 and 6). The references (Section 8.0) are divided into two parts for clarity. References I (Section 8.1) consists of a list of Rasmussen's papers and References II (Section 8.2) presents a list of the other documents cited in this paper.

2. Past researches on Rasmussen's approach

The ideas proposed by Rasmussen have been addressed historically by three researchers: Jean-Christophe Le Coze (2015), Penelope Sanderson (Sanderson and Harwood, 1988) and Kim Vicente (Vicente, 1997, 1998, 1999, 2001; Vicente and Sanderson, 1992). Sanderson and Harwood (1988) have developed an account explicating the growth of the Skills, Rules, Knowledge (SRK) taxonomy between the years 1969–1981. Whereas Vicente and Sanderson (1992) is a short note delineating the earliest use of the terms in the SRK framework and identifying the timeline in which it was framed. As opposed to the above two papers, Vicente (2001) has developed "a history of the context of justification" of research at Risø Laboratories for the years 1962–1979 (Vicente, 2001, 1998, p. 5; alsobib_Vicente_1998), whereas Vicente (1999, p. 361–365) features a short historical addendum outlining the human factors research program at Risø. In a recent review of Rasmussen's approach, Le Coze (2015) has emphasized the major themes throughout Rasmussen's career with a special emphasis towards safety science and macro issues related to risk and accidents. The current paper adds to the above list by presenting the major themes in Rasmussen's papers with special emphasis on the engineering dimension of his approach. This current article should be considered along with the ones presented by the above researchers for an overall understanding of Rasmussen's approach.

3. Historiographical method and scope

The focus of the present article is on an internalist approach towards the growth of ideas. It consists of all of Rasmussen's English language papers beginning from his earliest papers in 1961 up till 1986, when he published his book on cognitive engineering (see References I[2]for details). These documents include sole-authored and co-authored published articles, as well as work reports from Risø Laboratories, Denmark. Rasmussen's 1986 book outlined a major advancement for cognitive engineering and presented, in a consolidated manner, Rasmussen's viewpoint on man-machine systems design that was developed in the previous decades (Rasmussen, 1986). 1986 saw a shift in Rasmussen's focus, thus making it a natural endpoint. Le Coze (2015, p.130) notes that from 1987 onwards there was a clear shift towards the macro issues of accidents and safety in Rasmussen's approach.

I would like to emphasize that the current article is a historical paper addressing Rasmussen's approach. It is an essential task of the historian to bring to light the manner in which the historical actors themselves conceptualized and approached the problems they faced. This is the direction I have taken in the current manuscript based on the reading of Rasmussen papers as well as the supplementary background reading from the citations in his papers. The paper that I have written is a historical paper and brings to light the logic behind Rasmussen's work from 1961 to 1986 and the aspects that I am addressing are the ones that he has raised.

In this study, a few sources were consulted for a detailed analysis of Rasmussen's papers. First, a list of Rasmussen's papers was found in the appendix of the book *Tasks, Errors and Mental Models* (Goodstein et al., 1988, p. 335). Further, the Risø Laboratories research reports appearing in this list were cross-checked with the library catalogue of the Technical University of Denmark.[3] This step was taken in order to ensure that the list of documented papers was complete. For example, Rasmussen's paper "On the Communication between Operators and Instrumentation in Automatic Process Plants" initially appeared as a report (Risø-M-686) in 1968 (in this article, Rasmussen, 1968c) and was later published as a book chapter in 1974 (in this article, Rasmussen, 1974a). However, in the appendix of the book *Tasks, Errors and Mental Models,* this paper does not appear in 1968 as a work report, but does appear in 1974 as a published source. A third source of Rasmussen's papers was found in the collection of the Advanced Interface Design Lab (AIDL), University of Waterloo, Canada. This source also contained work reports and working papers that were not included in the appendix of the book *Tasks, Errors and Mental Models.* For example, Rasmussen's 1978 report "Operator/technician errors in calibration, setting, and testing nuclear power plant equipment" (N-17-78, May, 1978; in this paper Rasmussen, 1978d) does not appear as a work report for the year 1978 in the appendix of the book *Tasks, Errors and Mental Models*. However, in developing accounts of Rasmussen's research, others have referenced this paper (e.g., see Vicente, 1999, 2001). The list from AIDL includes these missing work reports and working papers. Therefore, the list of references (References I) used in this case study is an amalgamation of these three sources.

[2] While all documents have been studied and used for writing this thesis, they have not all been cited in the paper. Nevertheless they are important to the study and therefore have been presented in the reference section. A list of non-cited works that have been helpful in comprehending Rasmussen's approach have been placed at the end of this article. For a chronological summary of all the papers, see Kant, 2015, Appendix A.

[3] Risø Laboratories became a part of Denmark Technical University (http://www.risoecampus.dtu.dk/?sc_lang=en). The library catalog can be found at http://orbit.dtu.dk/en/.