Applied Ergonomics 59 (2017) 625–636

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Ecological interface design and system safety: One facet of Rasmussen's legacy

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ARTICLE INFO

Article history:
Received 9 April 2015
Received in revised form
22 July 2015
Accepted 4 August 2015
Available online 17 February 2016

Keywords:
Safety
Ecological interface design
Work domain analysis

ABSTRACT

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.

1. Introduction

> *In Gibson's terms, the designer must create a virtual ecology, which maps the relational invariants of the work system onto the interface in such a way that the user can read the relevant affordances for actions. (Rasmussen et al., 1994, p. 129)*

Advances in computer interface technologies (e.g., high-resolution, bit-mapped screens and input devices) have provided system designers with the capability to develop effective decision making and problem solving support. These technologies are inexpensive, powerful, and very mature. Furthermore, they complement the exquisite perception-action skills (e.g., spatial reasoning and pattern recognition) of the human in the control loop. As such, these interface technologies provide the very real potential to provide computerized support that leverages human strengths and improves overall human-machine system performance and safety. However, "… this potential is rarely realized; interfaces that are both intuitive and efficient (and therefore pleasurable to use) are the exception, rather than the rule." (Bennett and Flach, 2011, p. 10).

The pioneering work of Jens Rasmussen has provided a powerful legacy for realizing this potential on a more regular basis. His early work on cognitive systems engineering (CSE) at RISO (see Rasmussen, 1986, for a summary) laid the foundation. Subsequent collaborations with Vicente on ecological interface design (EID) crystallized these ideas in terms of decision making and problem solving support (Rasmussen and Vicente, 1989, 1990; Vicente and Rasmussen, 1990; Vicente and Rasmussen, 1992). This seminal work has been expanded upon by a number of researchers in the interim (e.g., Bennett and Flach, 2011; Burns and Hajdukiewicz, 2004; Flach et al., 1995; Hancock et al., 1995). Overall, the CSE/EID framework provides a principled, integrated approach to the analysis, design and evaluation of socio-technical systems.

We (Bennett and Flach, 1992, 2011) have characterized the CSE/EID framework as a "triadic approach" (see Fig. 1). Today's work is often "computer mediated": the "virtual ecology" (see the quote at the beginning of this section) of the interface stands between the worker and the work domain. From the CSE/EID perspective, the ultimate success or failure of an ecological interface will depend upon the quality of two sets of mappings. One set of mappings occur between the work domain (i.e., the ecology: the physical, social, and technical environment) and the interface (left and middle of Fig. 1): does the interface contain all of the information that is necessary for accomplishing work in that work domain? The second set of mappings occur between the interface and the worker (middle and right of Fig. 1): 1) have the representations been

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http://dx.doi.org/10.1016/j.apergo.2015.08.001
0003-6870/

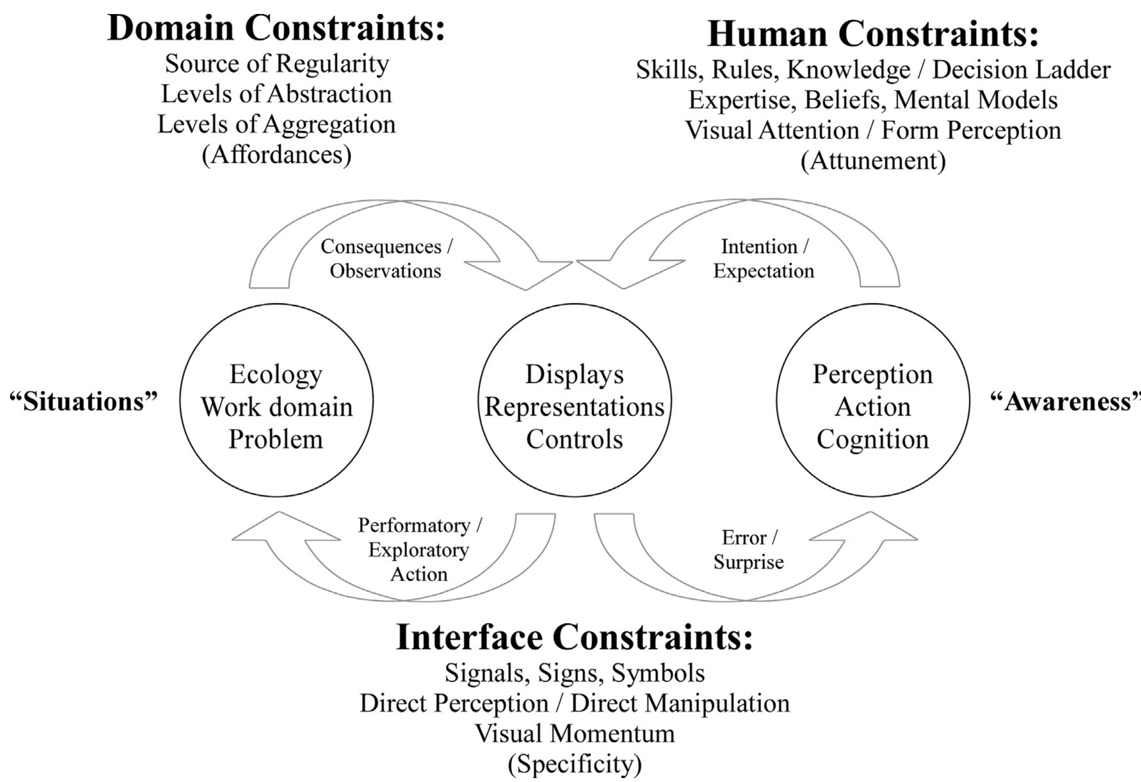

Fig. 1. Overview of the CSE/EID triadic framework.
Adapted with permission from Bennett, K. B., and Flach, J. M., Display and Interface Design: Subtle Science, Exact Art.

designed to allow the worker to pick-up information about the work domain easily? (i.e., perception), 2) has the worker learned to appreciate what these patterns mean? (i.e., expertise), and 3) have the controls been designed to allow the worker to execute control input effectively? (i.e., action). Thus, the goal of EID is to design computational tools (i.e., controls and displays) that support (rather than replace) workers in their decision making and problem solving activities by leveraging their powerful perception/action/cognitive capabilities. In the present manuscript we explore selected aspects of Rasmussen's legacy: the CSE/EID framework and some implications for system safety.

2. A brief review of the decision making and problem solving literatures

> *Increasingly, the primary reason people are present in complex sociotechnical systems is to play the role of knowledge worker by engaging in adaptive problem solving. (*Vicente, 2002*, p. 62)*

Decision making and problem solving are activities that have a direct relationship to system safety. In this section we consider the corresponding research literatures to identify the defining characteristics of these activities and the associated informational needs.

2.1. Decision making

Under normal operating conditions a worker is functioning as a decision maker. Historically, researchers have theorized that decision making involves optimization, a process that produces a single best outcome. The various dimensions of the decision are evaluated, specific values of these dimensions are weighted, all alternative responses are considered, and the most appropriate response is chosen. Decision making was viewed as a largely analytical process and the role of perception was essentially ignored.

In contrast, recent theories of decision making have emphasized, at least implicitly, the role of perception. For example, naturalistic decision making (e.g., recognition-primed decision making, Klein, 1989) places a premium on recognition (i.e., perceptual processes and the critical role that they play in decision making). Initially, experts utilize perceptual cues, in conjunction with their prior experience, to determine the prototypicality of a particular case (e.g., how is this case similar or dissimilar to those that I have encountered before?). Later, in the evaluation stage, visual or spatial reasoning (e.g., mental imagery) often plays an important role.

In contrast to classic decision making, proponents of naturalistic decision making view experts as generating and evaluating a few "good" alternatives with the potential to work, rather than the "optimal" solution. In Rasmussen's terms, workers are involved in skill-based (i.e., activities that engage the high-capacity, sensorymotor systems associated with perception and action) and rule-based (i.e., activities that involve the recognition of stereotypical situations and the execution of effective procedures that have been developed through prior experience) behaviors.

2.2. Problem solving

Workers in complex dynamic domains experiencing abnormal operating conditions are best characterized as problem solvers: a set of circumstances are present that have not been anticipated in the preparation of pre-planned guidance, training, or operating experience. Workers must detect the presence of an abnormality,