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Ergonomic field studies in a nuclear power plant control room

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Abstract

The safety and availability of sociotechnical critical systems still relies on human operators, both through human reliability and human ability to handle adequately unexpected events. This paper focuses on ergonomic field studies of nuclear power plant control room operator activities, and more specifically on the analysis of verbal communications within control room crews during micro incidents in normal operation. We show how operators use verbal exchanges to produce continuous, redundant, and recursive interactions to successfully construct and maintain individual and mutual awareness, which is paramount to achieve system stability and safety. Such continuous interactions enable the operators to prevent, detect and reverse system errors or flaws by anticipation or regulation. This study helps in providing cues for the design of more workable systems for nuclear power plant operation.

Keywords: Ergonomics; Safety; Procedures; NPP Operation

1. Introduction

The pre-defined organizational constructs (formal structures, procedures, methods, and plans) are an essential characteristic of the work in highly regulated domains such as the nuclear power plants (La Porte and Thomas, 1995; De Terssac and Leplat, 1990; De Tersac, 1992; Hirshhorn, 1993; Vicente, 1999). Several justifications frame this fact. For instance, from the cognitive point of view, procedures reduce the complexity level, allowing activities to be accomplished by using if-then rules, reducing the probability of human errors (Rasmussen and Jensen, 1974). The obligation to follow the procedures as a script, determining the action, reduces the workers' autonomy and variability, another possible source of human errors. Thus, the human reliability has been based on the strict execution of rules and procedures. In other words, the system only operates in conformity with its own safety specifications, if the actors accomplish their tasks, following strictly the formal organizational constructs, as defined by the designers and regulators.

On the other hand, ergonomics has been trying to demonstrate that the cognitive flexibility, local and contingent knowledge developed by the operators can be an effective way to reduce and correct errors. According to the Inherence Theory (Faverge, 1970, 1980), the operators can recover system errors; they adapt (Amalberti, 1992) and they are capable to interpret. The operators fill out the blanks and the implicit aspects of the procedures (De Tersac, 1992). For Amalberti (1996); Poyet (1990) to move away the humans from the direct control of production and to

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reduce the possibilities for human intervention would be harmful. This is especially true in situations of system disturbance, once humans develop strategies to deal with unexpected situations: "… operators are capable to resist and to update the prescriptions as a function of the activity context" (Poyet, 1990). The humans have a cognitive capacity that allows to judge qualitative aspects, a synthesis capacity for the interpretation of analog representations, a capacity to quickly reacts in response to the most probable cases (Rasmussen and Jensen, 1974). These are some of the reasons presented by ergonomics in order to consider the humans as recovering agents: the effective possibility to control the technical systems, many times restricted by the compulsory need to the procedures strict application.

We are not denying that human intervention changing set-points, procedures, rules, defined by Reason (1990) as violations—deliberate actions that deviate from the practices that designers and regulators have defined as necessary—can also have negative effects for safety. However, the ergonomics research findings have shown that interventions performed by humans at work are too often (and sometimes necessary) to be seen by themselves as generators of accidents. We will discuss the human interventions in rather neutral terms, as an expression of human cognitive flexibility.

After the literature review, we found only one systematic set of ergonomic field studies performed during NPPs actual operation. It was the set of field studies carried out in Canadian nuclear power plants (Vicente et al., 1997) investigating the impact of control room technology on operator monitoring activities. The studies findings emphasize the active problem-solving nature of the monitoring activities. According to Vicente and colleagues, the operators uses proactive strategies to cope with constraints imposed by the man-machine interface (e.g. changing variables set-points, alarms levels), indicating that actual monitoring activities can be quite different from the prescribed tasks. Thus, face the relevance of the findings, it was rather surprising that the literature review do not showed many more research about the topic, in different countries.

This highlight the importance of the work presented in this paper, which uses this underutilized methodology in examining NPP operation. In the following section, we will start the presentation of some field studies carried out in a nuclear power plant control room that shed some light on the discussion about human interventions and safety. The field studies results calls for a careful discussion, indicating that the routine violations (human interventions) cannot be considered an absolute negative value for safety. They have to be considered together with the operators' mental model and situation awareness (Endsley, 1997), along with the liberty that interventions allow on the system's configuration. The studies results will drive our set of recommendations.

2. Field studies in a NPP control room

Three field studies were carried out in one NPP control room and during simulator training. Although the methodological framework was quite similar for all studies, each one has particular aims and specific methods. Findings from the first study were used to guide the procedures for the second and third studies. The first study was conducted in order to get a better understanding of the NPP operators' work environment and activities during the work shift. In the second study, the activity of the operators during plant shutdown and start up was observed with the help of audio and video recordings. In the third study, in the NPP full scope simulator, we observed how operators dealt with the Safety Critical Function and Emergency Operation Procedures.

The field study methodology was based on activity analysis (Engenstrom, 2000), in which the subjects (NPP operators) are observed in their actual work setting. The basic steps of the methodology are systematic observation and register, inferences about cognitive activities, hypothesis formulation about cognitive activities and validation with the participants. The physical, organizational and cultural constraints function as the background under which the researches created their inferences and hypotheses.

This qualitative ethnographic framework implies that the researcher interact with the participants while collect empirical data. The observation in situ implies the daily taking of field notes (supported or not by electronic midia—audio and video recording) that record naturally occurring talks and interactions between observed actors. This strategy of gathering data allows grasping the vivid social scenes with accompanying conflicts, misunderstandings, processes of negotiation among actors, creations of consensual arrangements to disrespect prescriptive rules… that often come together with jargons, gestures, jokes, and so forth. Thus, the collection of empirical data is not independent from all these interactions occurring between the field observer and the insiders, and these interactions have to be considered as empirical data that will be classified in the moment of the theoretical analysis. This kind of applied ergonomic research tends to emphasize the work environment and what is imperative within that environment