Research on Task Types in Highly Automated Workstation: Implications for Job Design

Chunyu-Yu Chuang, Wei-Jung Shiang, Chiuhsiang Joe Lin, Tsung-Chieh Cheng, Liou Jin-Liang

***Abstract*—Automation has change the way human work and redefines the contents of job. A traditional task analysis approach usually has an observable process, emphasizes the behavior and the target performance desired. In contrast, cognitive task analysis has an unobservable process, emphasizes the inner information processing, and addresses knowledge structure base for the job. Before proceeding to perform task analysis, it is critical to make sure what the nature of task is. Many researchers consider that, with automation increasingly taking over plant tasks, cognitive operation will become the major behavior types in the operating processes. On the other hand, some scholars believe that even in highly-automatic stations the process was constrained by specific procedures no matter in routine or emergency conditions. In this study, three scenarios are selected and used to simulate and role-play by two operating crews. Empirical data was collected by four cameras and divided into skill-, rule- and knowledge-based behaviors according to time sequence classification model issued by IAEA. Time and frequency were calculated and analyzed by three different behavior types. Our research results show that rule-based behaviors were still the major type in the processes of operating, either execution time (rule-, knowledge-, skill-based: 67%, 24%, 9%) or frequency (rule-, knowledge-, skill-based: 71%, 18%, 11%). Especially to deserve to be mentioned, the knowledge-based behaviors were not the major-type behaviors in operating, but may be the key factors in determining success or failure. Our research suggests that, in addition to traditional task analysis, cognitive task analysis should be taken into consideration for a more comprehensive understanding of job design.**

Keywords: automation, digital workstations, job design,

I. Introduction

The industrial revolution brought large machines into the workplace; these were initially used to augment the man power. But following the digital revolution, converted the signal into binary code, has change the way human work. Binary code is a breakdown of complex signal into zeros and ones that can be processed by computer's central processing unit (CPU). After calculating and integrating processes, systems can achieve many functions automatically according to the requirements set by users, such as calibration, testing, validation, and even diagnostic, etc [1]. In place of traditional hard switch, video display units (VDUs) become the main human-system interfaces (HSIs) for operators to manipulate and monitor the status of the equipment, as shown in Figure 1[2]. Therefore digitalized workstations are very different from convention ones and the concepts of operations are changed hugely. The design and architecture of digital systems are inherently different from those of analog systems [3]. Automation has change the way human work, reduces the workload and risk [4].

On the other hand, certain human factor issues were raised with the change from manual to automatic operation [5]. Some of these are very important to production efficiency or human performance but neglected for a long time. For example, how the job to be design or redesign? The objective of job design is to systematic assign jobs which allow people to perform tasks in a safe, efficient, and economical manner. Successful job re/design is based on appropriate task analysis, to evaluate what people do, how they do it, and what results they achieve by doing it. A traditional task analysis approach usually has an observable process, emphasizes the behavior and the target performance desired [5]. In contrast to traditional task analysis, cognitive task analysis has an unobservable process, emphasizes the inner information processing, and addresses knowledge structure base for the job [6]. Before proceeding to perform task analysis, it is critical to make sure what the nature of task is. In other words, to know the behaviors that constitute the task is observable or unobservable, focusing on behavior or knowledge [6]?

Automation refers to the replacement of human manual control, planning and problem solving with automatic device and systems. Thus, many researchers believe that, with automation increasingly taking over plant tasks, the operator's behavior from mainly operation to mainly supervision. And the nature of task will be less skill-based and rule-based but more knowledge-based [7][8]. On the other hand, many scholars believe that even in a highly-automatic main control room the process was constrained by specific procedures no matter in routine or emergency conditions. [9].These procedures are formerly known as standard operating process (SOP) or emergency operating process (EOP). The natures of the tasks still belong to rule-based.

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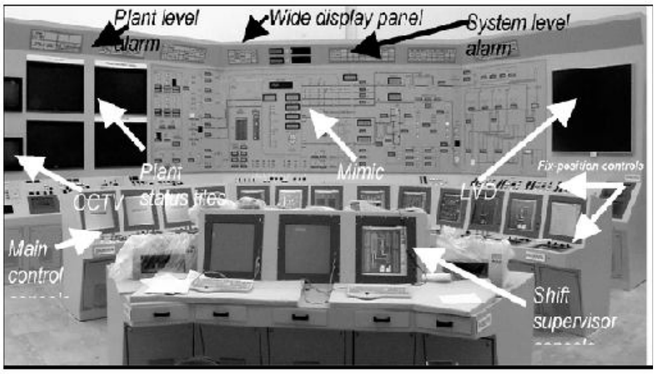

Fig.1 Advanced main control room of Lungmen nuclear power plant: An example of Highly-automatic workstation [2].

II. Experiment

A. Participants

The participants formed a three-member evaluation team and two three-member operating crews. Each operating crew contained one licensed shift supervisor (SS), reactor operator (RO) and assistant reactor operator (ARO).The operating crews consisted of Lungmen Nuclear Power Plant (LMNPP) operations personnel that have completed formal training on the simulator. The nuclear steam supply system (known as safety-related system) is taken care of by the RO, while the ARO is responsible for operations balance of plant system (known as non-safety related system). The SS deals with conditions of the nuclear power plant, operations oversight for technical and staff administration matters.

B. Scenarios

Scenarios are designed to represent a broad range of conditions that are feasible for system operation, to be evaluated that behaviors taken in workstations in emergency or abnormal conditions. Criteria for selecting scenarios to be role-played are the majority of scenarios should be similar to scenarios used for operator training and the types of failure events mentioned in NUREG-0711[10]. The test scenarios have predefined initial conditions, applicable symptoms, and expected system responses and plant behavior in scripts. Three role play scenarios were selected as follows table.

Table1. Three Selected Scenarios

No.	Selected Scenarios
1	LOCA with Loss of Off-Site Power.
2	Control rod groups failure to scram and fails to initiate SCRRI (ATWS).
3	Loss of Normal and Emergency Feedwater.

C. Procedure & Data Collection

Experiment is conducted using specially-selected scenarios in given initial conditions and applicable procedures. Each scenario is role-played twice by a different crew each time. And the order is unknown to the test subjects. Test operation crews are not aware of the specific scenario they conduct before start of a simulated scenario. Scenarios were run until a stable unit condition, or the onset of unit recovery operation, was reached. Empirical data is collected by simulator and video recording of chronological event logs in full scope simulator of Lungmen Nuclear Power Plant (LMNPP).

D. Analysis

Experiment data was integrated from the sources of simulator recording and video recordings and decomposed into sequenced tasks and behaviors. Time sequence classification model, reference of logic tree of SRK model developed by International Atomic Energy Agency (IAEA), was applied to divided behaviors data into skill-based, rule-based and knowledge-based behaviors.

E. Results

The results show that rule-based actions were still the major type of human behaviors, either average execution time (rule-based, knowledge-based, skill-based: 67%, 24%, 9%) or frequency (rule-based, knowledge-based, skill-based: 71%, 18%, 11%).

Table2. Average execution time of three different behaviors.

	Execution Time	Proposition
Rule-Based	50.3 min	67%
Knowledge-Based	18.1 min	24%
Skill-Based	6.5 min	9%

Table3. Average frequency of three different behaviors.

	Execution Time	Proposition
Rule-Based	30.5 times	71%
Knowledge-Based	7.8 times	18%
Skill-Based	4.3 times	11%

III. Conclusion

The results show that rule-based actions were still the major type of human behaviors, either execution time or frequency. Especially to deserve to be mentioned, the knowledge-based behaviors were not the major-type behaviors in operating, but may be the key factors in determining success or failure. Our research suggests that, in addition to traditional task analysis, cognitive task analysis should be taken into consideration for a more comprehensive understanding of job design

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