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Applications of integrated human error identification techniques on the chemical cylinder change task

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ABSTRACT

This paper outlines the human error identification (HEI) techniques that currently exist to assess latent human errors. Many formal error identification techniques have existed for years, but few have been validated to cover latent human error analysis in different domains. This study considers many possible error modes and influential factors, including external error modes, internal error modes, psychological error mechanisms, and performance shaping factors, and integrates several execution procedures and frameworks of HEI techniques. The case study in this research was the operational process of changing chemical cylinders in a factory. In addition, the integrated HEI method was used to assess the operational processes and the system's reliability. It was concluded that the integrated method is a valuable aid to develop much safer operational processes and can be used to predict human error rates on critical tasks in the plant.

1. Introduction

Since the industrial revolution, major industrial accidents have become more and more serious. The affected scopes have been broadened gradually due to the development of science and technology and the expansion of factories. Based on investigations of accidents during last few years, it was found that human error is still a critical contributing factor. The Major Accident Reporting System indicates that human error was responsible for 90% of accidents, most of which could have been prevented by management measures; thus, the importance of human factors in industrial safety and accident prevention is quite evident (Leva, 2005). Therefore, it is important to assess human reliability to ensure industrial safety.

With the progress of technology, the design of the human-machine system has become more and more complicated. In response to rapid and complex changes in nowadays work, the study of ergonomics hazards needs to be established (Niu, 2010). The response strategy to minimize the risk of human error is the extensive use of automated processes, taking into account capacity constraints and the security of the operators. Automation improves the performance of operations and reduces the workload of operators, and it has successfully terminated human error at the behavioral level. However, automation introduces other safety issues caused by human cognition and social context that are usually ignored (Cacciabue, 2004). Therefore, in order to make the assessment results more precise and complete in the process of evaluating a system's reliability, it is necessary to realize the human cognitive process in various contexts and in the assessment of the system's design.

Currently, the human error identification (HEI) technique is used extensively to analyze human operational errors. Even though these techniques have been available for decades and there are many methods for assessing human errors, they are not universal for each domain because the development process must match different industrial characteristics, e.g., nuclear power plants, aviation, and the traditional chemical industry. Baysari et al. (2011) have modified one of the HEI tool to include more systemic performance factors contributing to incident occurrence for Australian rail. Since the priorities and objectives of the analysis performed in each method are not entirely the same, the external behavioral responses of operators and the associated psychological reaction mechanisms are not completely understood. Thus, the objectives of this research are as follows:

(i) To integrate the existing HEI methods with the methods used in various domains.
(ii) To explore the logic of the analysis process to determine the pros and cons of each approach.
(iii) To develop an assessment process that can predict human errors more effectively using complementary approaches and by integrating the various HEI approaches.

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Sheridan (2008) concluded that zero risk is not achievable, but a thorough analysis is bound to effectively make the system safer.

The main objectives of this research were to examine the operational process of changing chemical cylinders in a manufactory and to use the integrated analysis method of the HEI approaches to assess the operational processes and overall reliability of the system.

2. Literature review

Human error may occur in any stage of human's information processing, but errors generally are found more frequently in the stages of decision making and executing various actions. In the processes of human-machine interaction, it is difficult to avoid human errors, especially when humans are under pressure or working in a noisy environment (Brigette and Peter, 2006). Therefore, the specific focuses of this research are the use of human factor engineering methods to explore the reasons for human error and the identification of latent human errors that may be easily overlooked.

2.1. Prediction of latent human errors

By investigating and researching past accidents to determine the links between various conditions and situations associated with the accidents, we can identify possible human actions to prevent the recurrence of such accidents (Goossens and Hale, 1997). The Root Cause Analysis (RCA) method has been used to determine the most basic causal relationships associated with operational deviations, so it is useful in identifying the risks and the defects of tasks in order to prevent accidents in the future. However, studies of various systems sometimes tend to focus on the events and components that present the most significant hazards and ignore other minor situations that could also be hazardous (Shan et al., 2011).

Currently, the design of human-machine systems is becoming more and more complex, and the design and widespread use of automated systems have changed people's roles. People's roles have changed gradually from being the active operator and decision-maker to being passive overseers and policymakers of automated processes. This change means there has been a dramatic increase in the cognitive functions and organizational factors required to evaluate the systems effectively (Cacciabue, 2000). However, at the present time, safety assessment and analysis are still conducted using past concepts and methods. The result is that system failures are usually attributed to the operational design of the system, and efforts to prevent such failures involve increasing the protective measures of the machine and the environment. Therefore, the focus of the analysis is still on how to avoid the occurrence of failures rather than on exploring and correcting the causes of the failures. The basic causes of such failures are various environmental factors and the psychological mechanisms of the personnel involved. Thus, the current approach to the analysis of failures neglects many potential errors and may even underestimate latent errors.

2.2. Human error identification methods (HEI)

Human error identification (HEI) methods are used to identify latent human or operational errors that may arise as a result of human-machine interactions in complex systems and to identify the casual factors, consequences, and recovery strategies associated with the errors (Stanton et al., 2005). The concept of HEI methods emphasizes the analysis and prediction of latent operational errors in human-machine interactions via the understanding of the characteristics of the task and the details of the actions the operators must implement (Dalijono et al., 2006).

HEI methods can be categorized into two types, i.e., qualitative and quantitative approaches. Qualitative approaches typically use the taxonomies of various error modes and apply these error modes to the analysis of the activity in question. Various such qualitative approaches exist, including the Systematic Human Error Reduction and Prediction Approach (SHERPA) (Embrey, 1986), the Human Error Template (HET) (Stanton et al., 2006), the Technique for the Retrospective and Predictive Analysis of Cognitive Errors (TRACEr) (Shorrock, 1997; Shorrock and Kirwan, 2002), and the Cognitive Reliability and Error Analysis Method (CREAM) (Hollnagel, 1998). All of these methods apply some specific error mode taxonomies of the domain to aid the analyst in identifying latent errors. Qualitative approaches are successful in terms of sensitivity, use limited resources, and are simpler and easier to apply than quantitative methods. However, they rely significantly on the subjective judgment of analysts, and, as a result, there are concerns about inter-analyst reliability and the intra-analyst reliability of error predictions (Stanton et al., 2005).

Quantitative methods are used to assign numerical probability values to the associated errors. One of these methods is the human error assessment and reduction technique (HEART) (Williams, 1986, 1988), which predicts and quantifies the likelihood of operational errors and system failure. The main advantage of quantitative methods is that they provide objective numerical data of the occurrence of errors, but they are difficult to use and may require more resources and extensive knowledge of mathematical procedures.

In addition to the two types of HEI methods discussed above, there are some other synthesis methods, such as the human error and recovery assessment framework (HERA) (Kirwan, 1998a, 1998b) that was developed for use with other HEI methods to identify more potential human errors. The summary of a few of the HEI methods that were reviewed is shown in Table 1.

The objectives of this research, which are different from the toolkit concept of HERA, are to integrate the framework and the concepts of the above HEI methods and to collate the error modes determined from various domains.

3. The methodological framework

This research integrates various current HEI techniques to develop a multi-dimensional and structural methodology and to determine a solution that would help operators avoid potential operational errors that they otherwise might make.

3.1. The integration of current HEI

In this research, the analysis process was based primarily on implementing the SHERPA process. In addition, other analysis

Table 1
The summary of HEI methods.

Approach	Type	Domain	Training time	Error modes	Execution time
SHERPA	Qualitative	Nuclear Power plant	Low	Insufficient	May be time consuming
HET	Qualitative	Aviation	Low	Insufficient	Quick and simple
TRACEr	Qualitative	Aviation	High	Sufficient	May be time consuming
CREAM	Qualitative	Generic	High	Sufficient	May be time consuming
HEART	Quantitative	Nuclear Power plant	Low	Insufficient	Quick and simple
HERA	Synthetic	Generic	High	Sufficient	May be time consuming