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Predictive use error analysis – Development of AEA, SHERPA and PHEA to better predict, identify and present use errors

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ABSTRACT

In health care, the use of technical equipment plays an integral part. To achieve a high level of patient safety, it is important to avoid use errors when handling equipment. Use errors can be mitigated by performing analyses of potential use errors during the design process. One proactive analytical method for use error analysis is Predictive Use Error Analysis (PUEA), which is a further development of the methods Action Error Analysis (AEA), Systematic Human Error Reduction and Prediction Approach (SHERPA) and Predictive Human Error Analysis (PHEA). PUEA employs a detailed process for breaking down the user's tasks into steps and then identifying and investigating potential errors of use for each step. Compared with other methods, it is significant in its use of two question levels, greater inclusion of human cognition theory and that the results of the analysis are presented in matrixes.

Relevance to industry: The PUEA method is useful to the industry for evaluating existing products or serving as an evaluation tool during the design process. For instance, the PUEA method has been used to evaluate user interface designs of home-care ventilators and dialysis machines. In addition, PUEA can be applied as a final risk assessment method assessment method in the product development process.

1. Introduction

Many accidents involve human errors. In regard to safety-critical equipment, it is especially important that the equipment is safe to use, for example, in the field of medical equipment (Liljegren, 2004; Liu, 2004; Norris, 2009). A step towards creating safe equipment is to try to identify and counteract human errors in advance. For the field of medical equipment, Zhang et al. (2005) write: "*Evaluating and predicting patient safety in medical device use is critical for developing interventions to reduce such error either by redesigning the devices or, if redesign is no option, by training the users on the identified trouble spots in the devices.*" Phipps et al. (2008) stress the importance of using a method for more detailed examination of errors as a basis for suggestions to improve quality and safety in the medical field. Furthermore, Drews et al. (2007), Benn et al. (2008), Boakes (2009) and Habraken et al. (2009) highlight the use of prospective and proactive risk analysis in health care.

The field that deals with risk analysis of human errors is called Human Reliability Assessment (HRA) (Embrey, 2004). The methods and techniques that are employed in HRA can be divided roughly into two groups: qualitative and quantitative methods (Embrey, 2004; Stanton and Baber, 1996). The qualitative methods, Human Error Identification (HEI), are employed to indicate which errors are likely, while the quantitative methods, Human Error Probabilities (HEP), are employed to predict the probability that a given error will occur.

Examples of methods for HEP are Human Error Assessment and Reduction Technique (HEART) (Williams, 1986), Technique for Human Error Reduction (THERP) (Swain and Guttman, 1983) and Justification of Human Error Data Information (JHEDI) (Kirwan, 1994). These methods use collected data on probabilities of human error as a basis for judging the total probability that a human will err in a given future situation.

Examples of qualitative techniques are Potential Human Error Cause Analysis (PHECA) (Whalley, 1988) and Task Analysis For Error Identification (TAFEI) (Baber and Stanton, 1994). These methods analyse the user's actions to indicate likely problem areas in a system in which human errors can occur. One method developed to investigate human error in medical equipment is Extended Hierarchical Task Analysis (EHTA) (Zhang et al., 2005). This method has been used to evaluate infusion pumps.

A well-used group of Human Error Identification (HEI) methods consists of Action Error Analysis (AEA) (Suokas, 1982; Taylor, 1979), Systematic Human Error Reduction and Prediction Approach

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(SHERPA) (Embrey, 1986; Harris et al., 2005) and Predictive Human Error Analysis (PHEA) (Baber and Stanton, 1996; Embrey, 2004, 1992). These methods originate from the analysis of the operators' work in the nuclear power and process industries. The methods' approach is to break down the operator's tasks into steps and, for each step, identify and investigate potential incorrect actions. In medical care, SHERPA is one of the methods used to investigate medication errors (Lane et al., 2006). AEA, SHERPA and PHEA have close similarities with the technical risk analysis method Failure Mode and Effect Analysis (FMEA), which is described by, for instance, Taylor (1994). FMEA has also been used to analyse Human Error and Human Factor aspects of the work to improve patient safety with medical equipment, for example, with a Radiation Therapy System (Israelski and Muto, 2005). One great weakness of this group of methods, however, is that they do not include much cognitive theory (Stanton and Baber, 1996; Toola, 1993).

The purpose of this paper is to present and discuss a further development of the methods AEA, SHERPA and PHEA named Predictive Use Error Analysis (PUEA). PUEA is a method that is useful in practical engineering work in the field of Human Factors Engineering (Chapanis, 1985) and Product Development (Ulrich and Eppinger, 2004) in the industry. The term 'Use Error' has been chosen to shift the focus away from errors that the user commits to errors that arise during the situation of use. PUEA involves an expanded analysis, more cognitive theory and an improved presentation of results compared with AEA, SHERPA and PHEA. As an example in the presentation of PUEA in this paper, a case study of a fictitious medical equipment interface will be employed (a home-care ventilator); however, the use of the method is not limited to applications in medical technology.

2. Original methods

2.1. Hierarchical Task Analysis

To enable analytical evaluation of a user interface with AEA, SHERPA or PHEA, knowledge is needed about the task to be performed with the help of the interface. A common method for analysing work tasks is Hierarchical Task Analysis (HTA) (Annett and Duncan, 1967; Stanton, 2006). The method breaks down a task into elements or sub-goals (Kirwan and Ainsworth, 1992). These become ever more detailed as the hierarchy is divided into ever smaller sub-tasks. The division continues until a stop criterion is reached, often when the sub-goal consists of only a single operation (*progressive re-description*).

HTA thus describes how the overall goal of the work task can be reached through sub-goals and plans. The results are usually presented in a hierarchical tree diagram. HTA is also employed as a basis for other analytical methods of interface design, such as Cognitive Walkthrough (Liljegren and Osvalder, 2004) and Task Analysis for Error Identification (Baber and Stanton, 1994).

2.2. A Short history of the development of AEA, SHERPA and PHEA

The history of the development of the methods AEA, SHERPA and PUEA goes back more than 25 years and is not entirely clear. These methods have probably influenced each other more than the references indicate. An initial presentation was made of the Action Error Method (Taylor, 1979). This later came to be known as Action Error Analysis (Taylor, 1981, 1982). Its current design was presented by Harms-Ringdal (2001) and has chiefly been used in risk analysis (Toola, 1993). Another starting point for the methods' development was Human Error Analysis by Reunanen and Suokas (1980), which was used for risk analysis in the process industry (Suokas, 1982). The name of this method was later changed to Action Error Analysis (Suokas, 1985, 1988) and then again when connected to the analysis of risk and safety (Leveson, 1995).

In 1986, Embrey presented the first version of SHERPA, which was intended to provide guidelines for human error reduction and quantification in nuclear power (Embrey, 1986). A refinement of the method into PHEA was then made by Embrey (1992) and used for risk analysis of operator work in the process industry. PHEA is simplified and more systematised in its procedure than SHERPA, but the direct connection with cognitive theory has been removed. The theory regarding Rasmussen's SRK model was removed from this version (Embrey and Reason, 1986; Rasmussen, 1983).

The SHERPA method, however, has survived in parallel with PHEA and later developed similarly to PHEA by simplification, more systematisation and the removal of the connection to cognitive theory. The subsequent version of SHERPA has been used in diverse areas such as investigating its usability in automatic machines for goods (Stanton and Baber, 2002), to predict design-included errors on a flight deck (Harris et al., 2005), in the medical field when analysing human factor aspects of anaesthetics practice (Phipps et al., 2008) and in medical administration work in a cardiac telemetry unit (Bhuvanesh et al., 2008). The current versions of AEA, SHERPA and PHEA thus show great similarities, which will be described in the next section.

2.3. Descriptions of AEA, SHERPA and PHEA

Descriptions follow of the methods, their similarities and differences based on recent descriptions published in the method literature: AEA (Leveson, 1995), PHEA (Embrey, 2004) and SHERPA (Stanton and Baber, 2005). The preparations for the methods are quite similar. First, the tasks are chosen that will be analysed. The tasks are of a type that human-machine interactions have significant influence on at the risk level and malfunctions in the technical system. Moreover, the user, the environment and the technical system must be defined and specified at a level of detail that is suitable for the analysis.

The first step of the methods is to determine the correct sequence of operations of the tasks that are to be analysed, i.e. to conduct a task analysis. For SHERPA and PHEA, the recommendation is to use Hierarchical Task Analysis (HTA).

Then there is a step that belongs only to SHERPA – Task Classification. Each bottom-level task (operation) in the HTA is assigned to one of five categories:

- Action (e.g. pressing a button)
- Retrieval (e.g. reading from a display)
- Checking (e.g. conducting a procedural check)
- Selection (e.g. choosing one alternative over another)
- Information communication (e.g. talking to another party)

The next step for all the methods is Error Identification. For SHERPA, this is done by associating plausible errors with each bottom-level task and task classification. The error association is aided by a list of credible errors. Table 1 shows the list from Stanton and Barber (2002).

In PHEA, the error identification is done in the same way but also includes a search for errors that can be associated with overlying tasks in the HTA as well as so-called planning errors. Here too, a list of credible errors is employed, like that for SHERPA in Table 1, though it is not identical. The main difference is that the list for PHEA also includes planning errors.

AEA normally has no list of credible errors, though some versions of the method employ a list of deviations in human actions (Taylor, 1981). This approach is similar to the technical risk analysis