Safety Science 76 (2015) 228–238

Contents lists available at ScienceDirect

Safety Science

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

Task complexity as a performance shaping factor: A review and recommendations in Standardized Plant Analysis Risk-Human Reliability Analysis (SPAR-H) adaption

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ARTICLE INFO

Article history:
Received 8 December 2014
Received in revised form 9 February 2015
Accepted 10 March 2015
Available online 29 March 2015

Keywords:
PetroHRA
Complexity
Task Complexity
Human Factors
Human Reliability Analysis

ABSTRACT

This review is part of the PetroHRA project that aims at adapting human reliability analysis to the petroleum industry. The different elements that make up complexity are reviewed through a thematic analysis which identified 83 complexity elements that were categorized into 13 complexity categories. Six of these were found to be relevant and were included in the "Task Complexity" performance shaping factor which is presented in this paper. The description of "Task Complexity" includes levels and multipliers.

1. Introduction

Quantitative Risk Analyses (QRAs) are approaches that look at accident scenarios and evaluate the overall safety of a system probabilistically. QRAs have been used in the Norwegian petroleum industry since the second part of the 1970s. Traditionally, the focus of QRAs has been almost exclusively on technical systems and capabilities with little attention to human and organizational factors (Skogdalen and Vinnem, 2011; Vinnem, 1998). Several recent recommendations have pointed toward the worth of including human and organizational factors, as well as incidents showing the potential costs of not including them (McAndrews, 2011; Report to the President, 2011; Skogdalen and Vinnem, 2011). It was recommended that the petroleum industry examine an industry that has successfully implemented human and organizational factors into its QRA; the commercial nuclear power industry (in the nuclear industry, these methods are called Probabilistic Risk Assessments (PRAs)) (Report to the President, 2011). The nuclear industry has done this through including Human Reliability Analysis (HRA) in their QRA. An HRA is defined as "any method by which human reliability is estimated" (Swain, 1990, p. 301) and generally consist of three parts: (1) identifying possible human errors and contributors, (2) model human error, and (3) quantify human error probabilities.

This paper is part of a project (the PetroHRA project; Laumann et al., 2014) that aims at adapting HRA to the petroleum industry. This project is funded by The Research Council of Norway, PETROMAKS program. Statoil and DNV GL are industry partners in this project, Institute for Energy Technology is the project owner and SINTEF, Idaho National Laboratory and Norwegian University of Science and Technology are participants. All parts of the HRA process will be evaluated and adjusted to suit the needs of the petroleum industry. The outcome of the project will be a guideline for a new HRA method called PetroHRA. The quantification part of the method will be adapted from one of the most frequently used HRA methods in the nuclear industry: the Standardized Plant Analysis Risk-Human Reliability Analysis method (SPAR-H; Gertman et al., 2005), which is an HRA method that estimates human error probabilities (HEPs) through eight performance shaping factors (PSFs). SPAR-H was developed by Idaho National Laboratories and funded by the U.S. Nuclear Regulatory Commission (Gertman et al., 2005). Industry-specific information will be used where possible, but, due to the severely limited amount of petroleum specific research on HEP and the effect of PSFs, the evaluation of the PSFs will mostly rely on general psychology studies, the knowledge of which scenarios are likely to be analyzed in an HRA, and the PSF structure as a whole to avoid double counting or omitting key aspects. Seven of the SPAR-H PSFs have already been evaluated (Laumann

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http://dx.doi.org/10.1016/j.ssci.2015.03.005
0925-7535/

and Rasmussen, 2014; Rasmussen and Laumann, 2014), and this paper will focus on the last PSF: "Complexity". There is a wide specter of factors that could make a task feel complex, including all the other PSFs in a method. If you have a lack of time, a poor human machine interface (HMI), or lack the necessary training, even a rather simple task could suddenly appear to be very complex. While this fits well with our everyday use of complexity, it can cause problems in an HRA analysis as some issues are attributed more than once (i.e., both in "Complexity" and another PSF). Due to these factors, "Complexity" is perhaps the most multifaceted PSFs in SPAR-H, and it makes it incredibly important to have a precise definition. Large discrepancies in how different analysts have interpreted the "Complexity" PSF in SPAR-H have been seen (Forester et al., 2012; Van der Merwe et al., 2014), indicating that a more precise definition could be valuable to the PetroHRA method. The "Complexity" PSF in SPAR-H has a significant correlation with several other PSFs (Boring et al., 2006). While some correlation is expected, the rather high correlations indicate that there could be problems in overlapping definitions, which could lead to both double counting and reduced inter-rater reliability (Liao et al., 2014; Van der Merwe et al., 2014).

In this paper, we present one of the PSFs in PetroHRA: "Task Complexity". We will present the literature review behind the PSF, our suggestion for what it should include, what levels it should have and how future work can improve this PSF.

1.1. SPAR-H

The SPAR-H method is an HRA method that estimates HEP through multiplying a nominal error rate with PSFs. PSFs represent aspects of individual characteristics, the environment, the organization, or the task that decrements or improves human performance, thereby increasing or decreasing the likelihood of human error (Boring and Blackman, 2007). The eight PSFs included in the SPAR-H method are "Available Time", "Stress/Stressors", "Complexity", "Experience/Training", "Procedures", "Ergonomics/HMI", "Fitness for Duty" and "Work Processes" (Gertman et al., 2005). SPAR-H (called Accident Sequence Precursor (ASP; Blackman and Byers, 1995) at the time) was created as a simplified version of THERP (Technique for Human Error Rate Prediction; Swain and Guttmann, 1983). Since the initial method, several updates have been published (for the history of the SPAR-H method, see Boring and Blackman, 2007). SPAR-H has seen widespread use from both the industry and regulators in its intended area of use (US nuclear power plants) and in other industries. SPAR-H has received criticism for relying too much on the analysts' judgments through not providing enough guidance as to which PSFs to choose, how to consider the PSFs together, and not giving sufficient guidance in the qualitative parts of the HRA process (Forester et al., 2012; Liao et al., 2014). One of the strengths of SPAR-H is that it is a simple method that gives clear indications to where the problem lies if a high HEP is found (Forester et al., 2012). This structure was also one of the reasons it was chosen as the main method of adaption for the quantification part of the PetroHRA method as it makes it easier to adapt to other industries.

1.2. PetroHRA

The PetroHRA method is an HRA method that is currently in development. The method includes guidelines for how to collect data, how to model an event and how to quantify the HEP though a nominal HEP and nine PSFs. The quantification part of the method is based on SPAR-H, and PetroHRA has the same quantification approach where the nominal HEP is multiplied by the multiplier PSFs to give a HEP for the task. The PSFs in the PetroHRA method are "Available Time", "Threat Stress", "Task Complexity", "Experience/Training", "Procedures", "Human Machine Interface", "Adequacy of Organization", "Teamwork" and "Ergonomics".

1.3. Complexity

Complexity has been studied from different perspectives in many research fields. However, what these different perspectives and fields have defined as complexity has differed, leading to difficulties when trying to generalize complexity or learn from other fields. Lloyd (2001) created a non-exhaustive list of over 40 different definitions of complexity. Within HRA literature, the term "complexity" is often used; however, in the complexity literature, several different forms of complexity are discussed (Gell-Mann, 1995; Lloyd, 2001). The phenomenon we are interested in is described as "task complexity" (Campbell, 1988; Lazzara et al., 2010). By looking only at this form of complexity (referred to either as "complexity" or "task complexity"), the number of definitions drops, although there are still at least 13 (Gill and Hicks, 2009).

The different complexity definitions can be divided into three perspectives: objective, subjective and relative (for a review on task characteristics used in defining task complexity, see Campbell, 1988):

- **Objective complexity** focuses only on the properties of the task and does not take into account the subjective perception and the individual differences in those conducting the task.
- **Subjective complexity** indirectly measures the task though perception of the performer. This can be done via self-report or physiological data through measuring, for example, heart rate, sweat and eye movement. If the necessary equipment, and a sample large enough to control for individual differences, is available, this measure can give valuable information about the complexity of the task.
- **Relative complexity** is based on the idea that complexity can only be seen as a relative relationship between the difficulty of the task and the capabilities of the individual performing the task.

Some definitions of complexity, such as those found in mathematics and programming, have a direct measure of complexity (e.g., code length and algorithmic complexity (Lloyd, 2001)). In softer sciences, an indirect measure is needed even in an objective perspective. There is a general acceptance toward the idea that complexity can be divided into a range of elements that influence the task's complexity. There is, however, no general acceptance on which element's complexity should be measured through, and many different models and scales for doing so exist (Boring et al., 2007).

1.4. Complexity in SPAR-H

Complexity in SPAR-H is defined as:

...how difficult the task is to perform in the given context. Complexity considers both the task and the environment in which it is to be performed. The more difficult the task is to perform, the greater the chance for human error. Similarly, the more ambiguous the task is, the greater the chance for human error. Complexity also considers the mental effort required, such as performing mental calculations, memory requirements, understanding the underlying model of how the system works, and relying on knowledge instead of training or practice. Complexity can also refer to physical efforts required, such as physical actions that are difficult because of complicated patterns of movements. [The figure is not included in this paper, the factors are listed below in this section] illustrates typical contributing factors to complexity. Identification of these complexity factors may be found in Braarud (1998), EPRI TR-100259 (1992),