Advances in Ergonomics in Manufacturing

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CHAPTER 42

A case study of participatory ergonomics in the quality assessment of a drilling “dog house”

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ABSTRACT

This case study reports on the quality assessment of a drilling cabin (i.e., a dog house) by using a Participatory Ergonomics (PE) approach to the Heuristic Evaluation (HE) compared to an operators’ self-reported measurement. In the quality assessment, self-reported rating techniques are broadly used by Human Factors (HF) practitioners with the aim of investigating the subjective components (e.g., satisfaction, comfort and self-efficacy) of the operator work. In the Participatory Heuristic Evaluation (PHE), HF experts evaluate the system together with work-domain experts to extend the detection coverage of potential criticisms in the human-system interaction. In this study, a sample of worldwide drillers reported on the perceived quality of the “dog-house” by a questionnaire, while another sample of drillers evaluated the same type of drilling cabin performing a PHE. Results showed that self-reported questionnaire was associated to higher levels of perceived quality with an undervaluation of potential criticisms. Differently, PHE detected more system’s issues thanks to a knowledge exchange between HF and work-domain experts.

Keywords: Drilling rigs, Participatory Ergonomics, Heuristic Evaluation
1 INTRODUCTION

Technological improvements in drilling domain have led towards a recent implementation of new systems and tools (e.g., hydraulic plants and digital displays). While the engineering is required to develop sophisticated, stable and performing systems, the challenge of the safety and quality management consists in the adequate use of methods and techniques aimed at investigating the interaction between the human operator and the system. Traditionally, the Human Factors (HF) and Ergonomics literature is the most comprehensive source of methodologies for investigating the human operator in complex systems. In this domain, the debate on the “qualitative vs. quantitative” approach is still open (see for example Dekker and Woods, 2002 for a discussion in the human-automation context). In the drilling industry, the technical development centered on the operator work is mostly recent and HF contributions are not many, yet. A recent study (Aas and Skramstad, 2010) carried out a first structured assessment of the industrial application of the seven part control center ergonomics design standard ISO 11064, in the Norwegian petroleum industry. The lack of a strong methodological and empirical background in this domain makes the methods selection critical. For example, empirical evidences are not available yet to know which measurement techniques are the most suitable for monitoring driller cognition and performance. Also, the work culture in this field is quite far from HF and Ergonomics knowledge: if an air traffic controller is used to pay attention to the interfaces layout and to his vigilance states, most of drillers assumes extreme physical and cognitive fatigue as obvious and unsolvable. This case study reports on a first attempt to investigate ergonomics and the human factors in a “dog house” on a drilling rig. The research was carried out within a wider R&D projects granted by the Drillmec Spa (a manufacturing company of drilling and workover rigs for onshore and offshore applications) to the Ergoproject Srl (a small company specialized in ergonomics and human factors). The methodological approach to current investigation mixed a quantitative measurement (a self-reported questionnaire) with qualitative and participatory inspections (semi-structured interviews and a participatory heuristics evaluation). This latter method was considered necessary to improve the operators’ awareness about ergonomics and to support them in the identification of potential system’s criticisms and stress sources. The hypothesis was to find a not strong consistence between findings obtained by the self-reported measurement and by the participatory inspections. The first step of the investigation was a series of semi-structured interviews to the drillers. The interviews were developed on the basis of the “scenario analysis” proposed in the CRIOP (A scenario method for CRisis Intervention and OPerability analysis; see Johnsen & Bjørkli, 2008). Four cognitive factors as partially defined in the Simple Model of Cognition (Hollnagel, 1998) and in the Endsley’s Situation Awareness model (1995) were investigated in these surveys. The factors were defined as follow:

- **Information monitoring** – The quality of data and warnings received by the operator.
- **Comprehension** – Integration and interpretation of data from indicators and
events from the external environment, into a meaningful whole.

*Decision making* – Consistency with the standardized procedures and adequate planning to respond to unexpected events (e.g., operative delays).

*Action implementation* – Execution of the planned actions by respecting the safety rules modality (i.e., without using controls and tools, improperly).

*Work environment* – A socio-technical factor proposed by the method for CRIOP aimed at investigating the potential issues related to environmental and procedural factors (e.g., lightness and temperature, presence of other operators in the workspace).

The ergonomic issues found by the interviews were evaluated by HF and work-domain experts by carrying out a Participatory Heuristics Evaluation (PHE). The heuristic inspection is a widely accepted technique in HF domain. For example, Nielsen (1994) provided ten useful principles to evaluate the design of the web pages. Also, the ISO 9241-110:2006 reports on seven “dialogue principles” to guide the design of the user-system interaction. Generally, a heuristic analysis requires to a panel of issue-domain experts to evaluate the level of consistency between the system’s features and the principles. Differently, PHE adds users (work-domain experts) to the list of expert inspectors under the heuristic evaluation (see also Muller et al., 1998). Finally, this case study represents a first attempt to define a common ergonomics and HF methodology for research and industry, in drilling domain.

2 METHODOLOGY

2.1 Participants

Fifteen drillers (all males; mean expertise = 15.1 years, SD = 8.11 years) were involved in this study. The drillers were from oil/gas extraction sites in North Italy (five out fifteen), France (six drillers), Scandinavia (two), Brazil (one) and Colombia (one).

Seven drillers (all males; mean expertise = 16.04 years, SD = 9.84 years) were involved in a participatory heuristic evaluation (PHE) together with three HF experts. The PHE was carried out throughout inspections at two Italian extraction sites and at the system simulator of the manufacturing company.

All drillers involved in the study were trained to the use of the systems according to the requirements provided by the manufacturing company and the industry normative.

2.2 The drilling “dog house”

In this study, it was assessed the quality of the “dog house” implemented in the on shore hydraulic drilling plants manufactured by the Drillmec SPA company (Piacenza, Italy). The driller’s workstation was in a prefabricated cabin mounted on the foot of the drilling rig. Inside the cabin, two instruments panels were one on the left and one on the right side of the driller; this latter was in front of a wide
windshield that allows monitoring the rig floor from his/her workstation.

As shown in Figure 1, a set of levers, knobs, push buttons and selectors were placed on the panels for activating and controlling several tools (e.g., top-drive and torque wrench), while a series of visual warnings and manometers indicated the systems states and the valves’ pressure changes.

2.3 Participatory approach to the quality assessment

Two HF experts carried out three on site investigations with the aim of inspecting the potential issues of the drillers work in the “dog house”. This activity was participated also by the R&D manager of the manufacturing company and by a total of seven expert drillers. At the beginning of each survey, a driller was required to simulate the main operative tasks (i.e. drilling, trip-in, trip-out and casing) reporting aloud on his actions, attention allocation, criticisms, doubts and/or general discomfort. After completing this simulation, the driller responded to a semi-structured interview that investigated on specific aspects of the work activity in terms of “information monitoring”, “comprehension”, “decision making”, “action implementation” and “work environment”. This participatory and qualitative investigation allowed identifying a series of system issues related to four main quality factors: “system visibility”, “error prevention”, “layout” and “work environment”. On the basis of well-known heuristics in human-system interaction domain (see for example, Nielsen, 1994 and ISO 9241-110:2006), a set of four general principles were defined for guiding the experts’ evaluation of the drilling “dog house”:

System visibility – The system should allow driller to be continuously informed about what the tools are going on, through visible indicators and an unobstructed view on the rig.
**Error prevention** – The system should conform to the driller’s physical and cognitive skills and constraints, without placing him/her in potentially unsafe or misunderstanding situations.

**Layout** – The objects’ positioning in the cabin should benefit the interfaces’ learnability in such a way that the driller can handle the controls keeping the eyes ahead, if necessary.

**Work environment** – The workspace should be free from discomfort and technical solutions should properly limit external stress factors that could negatively affect driller’s safety and performance.

The work-domain experts and the HF experts carried out a participatory heuristic evaluation by assessing the level of consistency between the system features and the “general principles”; the level of consistency was reported by inspectors on a 5-point Likert scale, as follows: “none”, “low”, “medium”, “high”, “complete”.

### 2.4 Self-reported quality questionnaire

The system’s issues found in the experts’ inspection were used for developing a series of statements included in a self-reported quality questionnaire. This measurement was considered necessary to enlarge the drillers’ sample both numerically and culturally (i.e., in terms of country of provenience). The items of the questionnaire were revised by a participatory activity that involved several stakeholders: the R&D manager of the manufacturing company, an expert driller and two HF specialists. The questionnaire aims to cover the four main factors defining the quality of the “dog house” (i.e., system visibility, error prevention, layout and work environment).

**Table 1. The twelve items of the questionnaire, separately for the quality factors used in the evaluation of the “dog house”.

<table>
<thead>
<tr>
<th>Quality factor</th>
<th>Questionnaire item</th>
</tr>
</thead>
<tbody>
<tr>
<td>System visibility</td>
<td>From the workstation, all displays and indicators / gauges can be adequately monitored “at a glance”.</td>
</tr>
<tr>
<td></td>
<td>From the workstation, it is easy to monitor the rig floor (e.g., tubes’ container, top drive and other staff).</td>
</tr>
<tr>
<td>Error prevention</td>
<td>During the operational activities, it happens to accidentally bump into some command.</td>
</tr>
<tr>
<td></td>
<td>While going to press or hold the necessary command, I get confused.</td>
</tr>
<tr>
<td>Layout</td>
<td>At the consoles all controls are “at hand”.</td>
</tr>
<tr>
<td></td>
<td>The controls on the dashboard are grouped and well separated between them.</td>
</tr>
</tbody>
</table>
Work environment

- The noise of the machines is too high.
- In the *dog house*, it is either too hot or too cold.
- The vibrations on the dashboard and on the seat make the work heavy.
- When it is sunny, the brightness in the *dog house* is annoying.
- The environment into the *dog house* is unhealthy because of the dust that comes from the outside.

The questionnaire was developed in a four-languages version (Italian, English, Spanish and French) and it was sent worldwide to the oil/gas extraction sites. After receiving the questionnaire, the drillers could express to what they agree/disagree with the list of statements by using a 5-point Likert scale, as follows: “Strongly disagree”, “Disagree”, “Neither agree nor disagree”, “Agree” and “Strongly agree”.

3. RESULTS

The evaluation scores (range 1-5) for each quality factor (system visibility, error prevention, layout, work environment) were used as dependent variable in a comparison between the “Participatory heuristic evaluation” (PHE) and the “Questionnaire”.

![Figure 2. Evaluation scores, separately for “Type of measurement” (participatory heuristic]
evaluation and questionnaire) and for “Quality factor” (system visibility, error prevention, layout and work environment).

Results showed that the self-reported evaluation by the questionnaire was associated to higher levels of perceived quality of the system for each factor, excluding the “error prevention”. In particular, the largest differences between the two methods were associated to the “layout” (MEAN = 3.93 SD = 0.53 by the questionnaire and MEAN = 1.67 SD = 1.15 by the PHE) and to the “system visibility” factor (MEAN = 3.83 SD = 0.52 by the questionnaire and MEAN = 2.67 SD = 1.15 by the PHE). Regards to the “work environment”, the two methods reported similar scores (MEAN = 3.21 SD = 0.44 from the questionnaire and MEAN = 2.67 SD = 0.58 from the PHE). Finally, the evaluation of the “error prevention” factor with questionnaire was associated to slightly lower scores respect to the PHE (MEAN = 3.58 SD = 0.54 and MEAN = 4.33 SD = 0.58, respectively).

4. CONCLUSIONS

In the drilling domain, the recent change from mechanical to hydraulic systems makes available the implementation of new technological solutions that could improve operators’ comfort and performance. This technical evolution requires a deeper knowledge of the human operator to center the future system design on his/her skills and constraints. The case study described in this chapter represents a first attempt to identify a suitable HF method to investigate human operator (i.e., the driller) in drilling domain. In particular, a self-reported questionnaire and a participatory heuristic evaluation were mixed and compared between them. Results showed that the operators undervalued potential criticisms and reported a better quality of the workspace by using the self-reported method. Differently, when the operators were involved in a participatory evaluation they showed a better sensitivity to both systems’ criticisms and not-comfortable situations. In other words, a participatory approach (including HF and work-domain experts in the evaluation) showed to cover a wider range of potential issues. Of course, these results showed some preliminary evidence that future studies should confirm and validate involving a larger sample of participants (both HF experts and operators). The final aim of this research is to find a valid and reliable methodology to investigate the operator interaction with novel technologies in drilling domain.

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