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Development of a Model for the Integration of Human Factors in Cyber-physical Production Systems

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Abstract

The ongoing introduction of cyber-physical systems in many areas of manufacturing will create profound changes in work design. Examples are new computerized tools or changed tasks due to a new allocation of work tasks between humans and machines. Hence the possible utilization of the potential enabled by cyber-physical production systems highly depends to what extent they are designed for humans. Therefore, an integrated system design is required which includes the human factors at an early stage.

This work serves as a starting point for the development of a design-to-human factors for cyber-physical production systems. On the basis of the present state-of-the-art of relevant scientific research a hypothetical model is developed, which shows the interdependencies between human-oriented work design and the resulting job performance in regard of cyber-physical production systems. We use an interdisciplinary approach consisting of research and findings from human factors, ergonomics, human-machine-interaction and work psychology in connection with engineering goals. The resulting model provides exemplary work design actions for cyber-physical production systems.

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Keywords: Human Factors; Cyber-physical production systems; Work area design; Digitalisation; Automation

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1. Introduction

Current trends and implementation examples of cyber-physical production systems indicate profound changes regarding human work tasks on the machine floor. The new tasks contain a larger variety of subtasks and a different set of subtasks due to a changed subdivision of tasks among humans and machines. Further, more interactions between humans and machines are required. Besides, alongside the introduction of an autonomously organized production, hybrid manufacturing systems will be established. Hybrid production systems enable decision-making by both humans and machines and require a mutual perception and consideration. These technological changes lead to subsequent changes in work design. How do the new jobs have to look like to fit these new requirements? Hence, for example, critical design principles have to be identified and their influence on work performance and efficiency has to be determined. Furthermore, more findings regarding the well-being and job motivation of workers in relation to the new work conditions are necessary as well.

The paper at hand mainly deals with an examination of available knowledge in work design regarding its applicability for cyber-physical production systems. Firstly, we provide a brief summary of work area design research and basic principles of human-machine-interaction. Secondly, we focus on recent developments and trend predictions on changes in manufacturing work caused by cyber-physical production systems. In the following, a model is developed, which is based on classic work design concepts, but has been extended by the requirements and characteristics of cyber-physical production systems. The model is intended to serve as a starting point for further research towards a set of design principles for human work systems in the factories of the future. Due to the fact that a major part of the scientific community of this topic is publishing their work with references to Germany or the German manufacturing sector, many relevant publications are only available in German language. Consequently, the ratio of non-English language references in this paper is slightly higher.

2. Work design research

2.1. Basic information

The field of work design deals with actions, which lead to a change of existing work areas or to the establishment of new work areas. It consists of the design of the work organization, connections to other work areas, tasks, work equipment, work places or work environment. From an economic and engineering point of view, work design aims at an increase of performance and efficiency of the value-added process. Besides, from a human-oriented point of view, it also deals with the creation of jobs, which enable a safe and neither physical nor mental exhaustive way of working [1]. Figure 1 provides an overview of possible starting points for work design actions and shows related objectives as well.

The choice of suitable work design actions is usually performed on the basis of an analysis of the existing work system. Here, all involved stakeholders should participate. An evaluation of possible work design actions is carried out by the application of ergonomic and work psychological criteria [1]. Fundamental contributions regarding these criteria have been made by Rohmert [2] and Ulich [3] (see Table 1). Both approaches consider a certain set of criteria, which apply on either physical (feasible, tolerable, reasonable, non-damaging and non-impairing tasks) or mental (satisfying and personally beneficially tasks) human needs. Here, for example, the criterion feasibility deals with the question whether the tasks fit the human capabilities. Personally beneficially tasks, however, do not just deal with the tasks itself but also whether it leads workers to learning on the job.

The major difference can be found regarding their hierarchical order. Here, Rohmert considers the criteria being in ascending order. Therefore, work tasks should be optimized following this classification, starting with the lowest number [2]. In contrast, from Ulich's point of view, the criteria should be optimized equally. He argues, that every criterion can contribute to the work perception regardless the optimization of any other criteria [1][3].