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KOMPASS: a method for complementary function allocation in automated work systems

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A method supporting complementary function allocation in automated work systems called KOMPASS will be presented. KOMPASS supports interdisciplinary design teams in deciding about function allocation in automated systems, taking into account the need for an integral consideration of people-related, technological and organizational factors in the design of work systems in order to satisfy the demands for effectiveness and safety of the overall work system as well as for motivating jobs for the human operators. A set of empirically tested criteria for the evaluation of the complementarity of system design forms the basis of guidelines for the analysis of work systems, individual tasks and human–machine systems as well as for a heuristic for system design. The method is described, including a practical example of an automation project to which it was applied.

1. Introduction

New production concepts geared towards dealing with highly complex products and production processes as well as fast changes in production demands call for an integral approach to technical, job and organizational design (e.g. Karwowski *et al*., 1994; Ulich, 1998). A crucial decision in the design of a production system concerns its degree of automation, which includes the allocation of functions between human operator and technical system. This decision has important consequences for the specification of technical requirements, for the design of the jobs of future operators of the system, and for the efficiency, quality and safety of the production process. The allocation of functions will significantly affect system flexibility, not only because machines are still —despite the development of flexible manufacturing technologies—inflexible by comparison, but also because functions can be allocated in a way that renders it very difficult or even impossible for the human operator to use his or her flexibility. Two concerns in this context are (1) the opportunities for the development and maintenance of practical production skills provided by a given allocation of functions and (2) the shift generally required in more automated systems from practical to theoretical systems knowledge (e.g. Duncan, 1981; Sonntag, 1990; Böhle & Rose, 1992). How both of these concerns are handled in terms of technical and job design as well as qualification of the operator will strongly influence the degree to which human potential can be employed.

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In order to explicitly address the interactions between technological, organizational and people-related factors in the design process, system designers need methods which permit on the one hand an analysis of tasks to be performed both in existing and planned work systems and on the other hand support them in the design process taking into consideration those interactions. Such methods should neither focus on requirements and consequences for the human operator alone, nor should they provide solely an abstract list of functional or technical requirements. Instead, task analysis and system design methods should enable the design team to evaluate the interplay of task definitions at the work system level, the individual job holder level and the human–machine system level, and to define and evaluate functions as components of these tasks in order to decide on their allocation in a sociotechnical system.

With KOMPASS, a method for task analysis and system design is provided which takes into account the need for an integrated consideration of technological, organizational and people-related factors. In accordance with normative approaches to job and organizational design stemming from humanistic psychology, action theory and sociotechnical systems theory (e.g. Hackman & Oldham, 1976; Susman, 1976; Hacker, 1986; Oesterreich & Volpert, 1986; Pasmore, 1988; Ulich, 1998), KOMPASS is based on criteria derived from requirements for motivating and competence furthering tasks as well as for high levels of individual and collective self-regulation.

Next, the theoretical background of KOMPASS and the proposed design criteria will be discussed. Then, the design method will be presented and illustrated by means of a case in which KOMPASS was applied.

2. Complementary system design

The increasing level of automation which characterizes modern technical systems, has proven to potentially endanger the efficiency and safety of production processes (e.g. Bainbridge, 1982). The human operators are not able to satisfactorily fulfill the basic requirements of their task as "supervisory controllers" (Sheridan, 1987) because they cannot develop sufficient knowledge of the system and the necessary production skills, nor maintain adequate situation awareness during operation of the system. Human control of technical systems, based on an understanding of the technical processes and adequate opportunities to influence those processes, is seen as a prerequisite for system safety and efficiency (e.g. Norman, 1986; Parasuraman & Riley, 1997). The operator's opportunity to develop adequate mental models of the technical system and of its processes and his ability to intervene properly depends essentially on the task allocation between him and the technical system, but also on the task allocation between him and other members of the work system.

With reference to Bailey (1989), five principles of function allocation between human and technology can be distinguished which are based on different perceptions of the roles of humans and technology (cf. Table 1). Frequent failures in system design have been caused by following the first three principles: cost efficiency (i.e. functions are allocated to human or machine according to short-term economic considerations), leftover (i.e. functions are automated as much as possible assigning the human operator just those functions that cannot be automated) and comparison (i.e. a function is allocated to the human if he/she supposedly performs it better than the machine and vice versa). These