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A Swedish industrial research program 'Co-operative for Optimization of industrial production systems regarding Productivity and Ergonomics' (COPE)

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Background

Large resources have been invested in ergonomic interventions during recent decades in Sweden. All the same, disorders in muscles and joints constitute a major occupational health problem. One explanation may be that efforts have been carried out by experts concentrating on isolated technical issues in running production, thus disregarding that exposures - and hence disorders - are primarily the result of the production system design.

To-day, most production systems undergo continuous changes aiming at improved productivity and product quality. Many of these changes also have ergonomic consequences. An appropriate superior aim of integrated ergonomic Research and Development (R&D) could thus be to develop tools allowing those engaged in developing the production system (e.g. engineers, operators) to integrate productivity and ergonomic issues when developing the production system (Engström and Medbo 1997, Winkel and Westgaard 1996).

This view forms the base of a new R&D program entitled COPE (cf. title), engaging in total about 20 researchers. COPE conducts R&D in companies showing a pronounced initiative in the cooperation with the COPE research teams. The cooperation is intended to generate both generalizable data (i.e. Research) and results directly applicable in the investigated company (i.e. Development). COPE comprises several distinct projects within three areas: (1) development of methods to describe, quantify and evaluate production systems regarding ergonomics and production engineering, (2) application of these tools to explore relationships between ergonomic and production engineering factors in production systems, (3) implementation of this knowledge in developing production systems. The latter issue mainly focuses development of a 'tool box' of methods to be used by company stakeholders when optimizing production system design. Below three case studies are presented, illustrating the COPE approach of integrated R&D.

Case 1A and B: Automobile assembly - materials kitting

Materials supply to parallel flow automobile assembly requires kitting of the materials, i.e. composing material kits for each individual product by picking components from storage packages to picking packages. Two principally different kitting methods exist: (1) conventional picker-to-part, and (2) part-to-picker. The latter method has proved to be potentially more efficient. Two case studies of part-to-picker kitting methods have been conducted in the COPE program, in two different companies producing kits for automobile assembly. In both companies, a kit comprised approximately 25 60x40cm plastic boxes, each containing 10 to 20 components.

In case 1A, the company initiated the collaboration with COPE, having realized that the materials kitting was inefficient and presented ergonomic problems. In case 1B, results from case 1A was to be integrated in the design of materials kitting in a new larger plant. This generated the need for methods predicting the integrated engineering and ergonomic consequences of various virtual design solutions, as well as methods acknowledging the professional competence of the operators in a participative approach.

A common basis for these developments of method was detailed, continuous whole-day video recordings of the operators at work. The recordings were initially decomposed by engineers into about 25 production-related activities performed by the operator. The activities were analyzed in terms of efficiency using production engineering techniques resulting in a discrimination between value-adding and non-value-adding operations, i.e. 'necessary work' and 'losses' (figure 1). The activities were regarded as basic building blocks even in a future production system, and the derived time specifications allowed consequences of different design solutions to be predicted and discussed before implementation. The ergonomic analysis of the production system adhered to this activity analysis. During the entire observation day, the operator carried ambulatory data loggers recording muscle activity (EMG) in the shoulders and arms, inclination of head, upper back and upper arms, as well as wrist angles (Hansson et al. 1996). By means of a radio transmitter, simultaneous event marks could be placed on the video recordings and on the data logger files, allowing a synchronization of the video-based activity decomposition with the recordings of mechanical exposure.

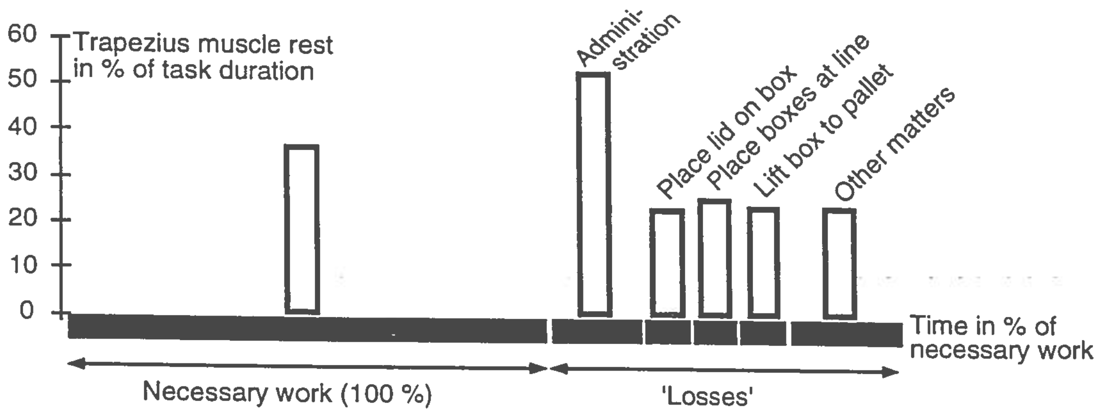

Figure 1. Efficiency analysis of materials kitting, and associated fraction of 'muscular rest' for each identified activity. One subject.

These synchronized data (figure 1) allow for an integrated determination of resource consumption and mechanical exposure at the level of product, work task or production system, even in virtual solutions (Mathiassen and Winkel 1997). In the present case, for instance, a future reduction in the proportion of administrative tasks (figure 1) would be predicted to increase efficiency but reduce trapezius muscle rest.

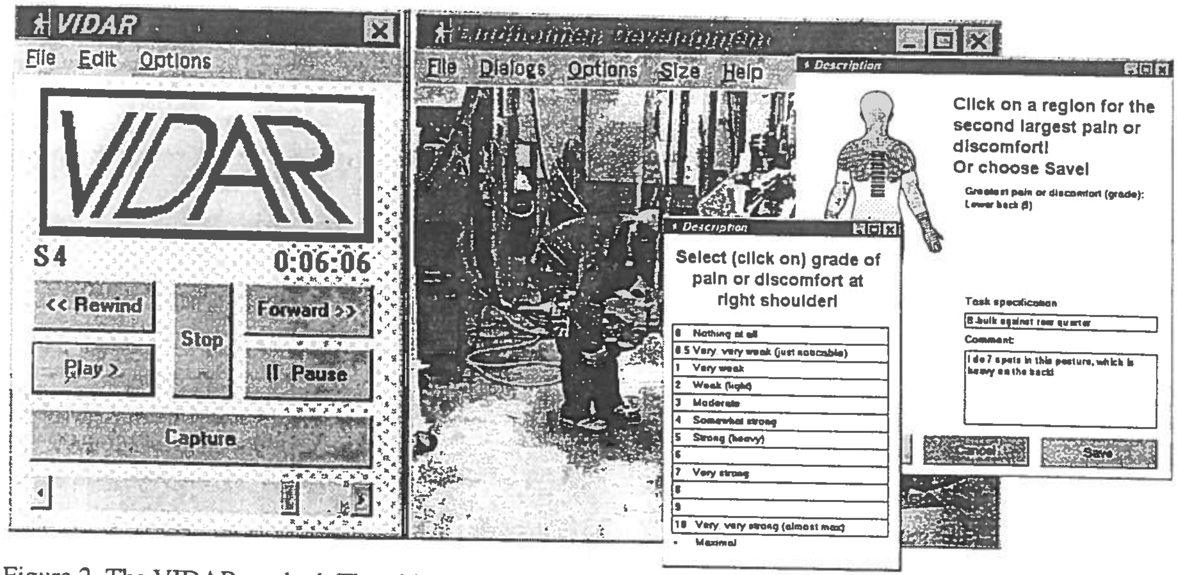

Figure 2. The VIDAR method. The video recorded sequence of work is displayed on the screen, and a virtual control panel is shown to the operator. When the operator clicks on a situation inducing pain or discomfort, the body map menu is opened. The worker clicks on the affected body regions and rates the pain or discomfort on the rating scale. This example is taken from case 2 (described below).

To ensure participation in the development process, two major tools were applied and further developed in the case 1A. First, the video recordings were applied in the VIDAR method for identification of work situations associated with pain or discomfort (Kadefors and Forsman 1997, figure 2). In VIDAR, the video is displayed on a computer screen, and the filmed operator assesses the work using virtual controls. The operator is asked to rate perceived exertion according to body region. A library is created in the computer, including task and operator identification data, ergonomic data, and pictorial information. Application of VIDAR shows that operators are able to understand and use the method after a brief instruction, and that VIDAR seems to be a useful tool in a participatory change process.

In addition to VIDAR, participation was obtained by forming a small multidisciplinary group consisting of operators and representatives of industrial engineering, work place design, ergonomics and organization. The group discussed and suggested problem solutions, using a CAD-program for visualization.

Both the synchronized activity analysis technique and the participative VIDAR and CAD visualization methods have been applied and refined in subsequent case studies in COPE, including the following.

Case 2: Welding of automotive bodies

In cooperation with a company in the automotive industry, welding of automotive bodies is investigated. The production system studied is under running-in. Extensive modifications are needed, in part due to the product design not being fully suited for mass production. The changes include, e.g. revised welding sequences and additional robots or robot stations, and require the opinions and suggestions of the operators. In connection with this case, a questionnaire tool is developed, one aim of which is to link production system design to ergonomic aspects. The questionnaire contains questions concerning background data, work contents, working hours, wages, work teams, work pace, production flow, physical exertion, and disorders.

In addition, the VIDAR method was further developed to include assessment of specific unsatisfactory psychosocial situations during work (Johansson 1995). This 'PSIDAR' method utilizes video-computer communication for assessment of, for instance, one working day, with regard to e.g. low control and high job demands, based on the individual's own perception and cognition. For instance, the operator may recognize specific situations such as materials missing, administrative faultiness and misplaced pallets or boxes. PSIDAR has so-far shown to be an attractive complement to traditional methods within industrial psychology and ergonomics.

Case 3: Bus assembly

A demanding process in manufacturing industry is the design and planning for production of a new product, particularly when it requires complex assembly. It is often difficult to articulate the ergonomic demands in a way which results in ergonomic factors being duly considered. In a cooperative effort with Volvo Buses, Borås, Sweden, COPE endeavors to develop methods to predict the ergonomic consequences of decisions made in the early design stage of a new product model, and to help ascertain that the eventual production system meets high standards regarding productivity as well as ergonomics. COPE was involved in the development process two years ahead of the planned release of the new product. At this early stage, the 'old' production system was documented using a modified activity- and exposure analysis based on video recordings. The company identified elements in the production process which presented both technical and ergonomic problems and therefore were to be changed in connection with the 'new' production. With the participation of the operators, alternative designs of the assembly docks are now being developed, using e.g. CAD visualizations. Solutions for the materials handling system in the assembly workshop are developed in cooperation with the production engineers of the company.

Activities presenting especially prominent ergonomic problems are examined in controlled laboratory mock-up experiments. The first laboratory simulation has concerned tightening of screw joints of different dimension and stiffness, in a variety of postures relevant to future production. Mechanical exposure has been assessed by EMG from the shoulder and lower arm, and by inclinometers on the head, arms and back. The results from these studies are fed back to the company as part of the iterative participatory process of developing an efficient, yet ergonomically