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EVALUATION OF MANUAL WORK BY SYNCHRONISING VIDEO RECORDINGS AND PHYSIOLOGICAL MEASUREMENTS

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ABSTRACT

Industrial interventions that focus on increased productivity may impair the ergonomics, on e.g. workstation or individual level. A goal of ours is to assign detailed ergonomic information to work activities. This paper presents a method that characterises work time consumption and physical exposure of manual work, through synchronising technical recordings of physical exposure with video recordings. The method has been developed through two case studies within the Swedish automotive industry, where manual materials handling was studied. A result from the case studies was that the synchronising procedure was sufficiently precise to allow different work activities to be assigned significantly different levels of physical exposure. It was concluded that the method is accurate enough to be a useful tool in interventions.

1 INTRODUCTION

Industrial interventions that focus on increased productivity may impair the ergonomics, on e.g. work-station or individual level. Even interventions that focus on ergonomics may fail in fulfilling their purpose [1]. Briefly explained, these phenomena are due to the fact that the scientifically based ergonomic interventions are mainly derived from experiments in laboratories, experiments that do not fully reflect all aspects of the industrial environment. On the other hand, due to the general lack of scientifically based guidelines regarding exposure limit values for manual work, the practitioners are prone to set these guidelines themselves. Which in practice means that e.g. large industrial projects, like the design of an automotive plant, are in fact progressing with a lack of scientifically based ergonomic guidelines using de facto values stipulated by industrial experiences.

Of course, laboratory experiments have advantages, they facilitate e.g. detailed studies of various ergonomic factors during controlled conditions. However, extending the laboratory studies to replicate industrial environments is time consuming, costly, and results in many cases in deficient replications. Thus, we have chosen to focus on field studies, and to develop a method that can give precise information from measurements in industrial work environments.

The underlying hypothesis for this work is that it is possible to amalgamate human and technical aspects, resulting in a synergetic evaluation (see Figure 1), in a way that accomplish industrial interventions. This paper

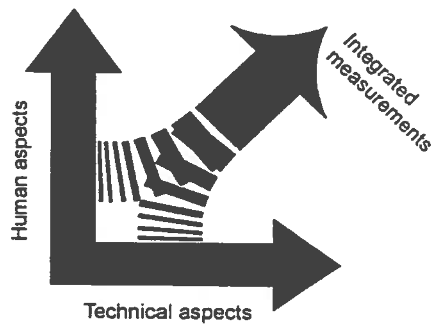

Figure 1. Schematisation of the hypothesis that it is possible to amalgamate human and technical aspects by integrated measurements leading to a synergetic evaluation.

presents a method for characterising manual work, through synchronising technical recordings of physical exposure with video recordings. The video recordings are used to identify the time consumption of different work activities. The synchronisation facilitates assignments of detailed ergonomic information to the work activities. A key factor in this evaluation procedure is the precision of the synchronisation.

2 METHODS

The technical aspects of Figure 1 were represented by the results from a computer- and video-based observation method for time data collection. The human aspects included physiological measurements of muscular activity and of body joint angles (postures and movements of the head, upper back and upper arms). The principle of synchronising the aspects is the same for different physiological measures, therefore only muscular activity was included in this paper. Other physiological measurements may of course be added.

2.1 Time Consumption of Work Activities

Through previous projects, we have developed a method for data collection and analysis of time consumption [2]. The method involves video recording of a working operator, and time coding of the videotape. The work is divided into work activities according to work elements, materials flow, body positions etc. The method, comprising software and a computer connected to video recorder, may be utilised for different types of analyses, e.g. to measure the efficiency of a production system by separating between value and non-value adding work activities. For example, full-pace assembly work of different operators has been analysed [3]. Hence, this video based method enables us to define appropriate work activities, the time periods of which are registered in a file with a precision of up to 0.04 seconds (one video frame; standard frame frequency, 25 Hz).

2.2 Electromyography

Muscular activity of was taken as a measure of physical exposure. The muscular activity was recorded in the shoulders (the trapezius muscles) and the forearms (the extensor muscles) using surface electromyography (EMG). The muscular activity during work was normalised to the maximal EMG (MVE), recorded during maximal voluntary contractions (MVCs). The MVCs were, for the trapezius muscles, performed as arm abductions at 90° in the scapular plane, and, for the extensor muscles, as maximal handgrip tests. For details on skin preparation, electrodes and MVCs, see [4].

EMG were acquired, with a sampling frequency of 1024 Hz per channel, using flash-memory based ambulatory data loggers [5]. After recording, data was transferred to a personal computer for processing. The root mean square (RMS) values were calculated for epochs of 128 samples, thus characterising muscle activity with a resolution of 8 Hz [6]. Since the raw EMG signal stochastically alters around zero, the RMS calculation is essential. The time resolution, here 0.125 seconds, is set by the chosen epoch length, which in turn determines the variance (short length gives large variance) of each RMS value as an estimator of muscular activity.

2.3 Synchronisation of Work Activities and Electromyographic Data

To facilitate synchronisation of the video recording with the physiological measurements, a remote-control-unit was used to mark a sample in the logger and lit a light emitting diode. The video frame of this event was identified in the computer program. The video-based method was also used to identify the time-windows for a set of defined work activities. These time-windows were, after a digital synchronisation to the logger data, used to extract statistics of muscular activity for the different work activities. For these calculations, a macro was written in Microsoft Excel. Moreover, to observe the EMG during specific situations, the synchronisation made it possible to use SEIP (Synchronised Exposure and Image Presentation); a computer program that displays EMG next to the video image on a computer screen [7].

3 THE CASE STUDIES

The new method was developed through two case studies within the Swedish automotive industry, where manual materials handling work was studied materials handling i.e. kitting of materials. The studies were carried out in two parallel flow automobile plant. In such a plant materials feeding techniques calls for kitting of the materials, i.e. composing kits of materials, for each individual product, by picking components from storage packages to picking packages. There are two principally different kitting methods, (1) conventional picker-to-part and (2) part-to-picker. The last kitting method has proved to have an efficiency potential [8], it was also used in both plants.

To evaluate the kitting work it was necessary to divide the work into work activities at a specific level of detail, a goal was to assign these work activities (in addition to product and process properties) detailed ergonomic properties. Twenty-five different activities where forming groups of direct and indirect work activities (i.e. related to value and non-value adding work).

Seven and four (Case 1 and Case 2, respectively) operators were continuously video recorded for four hours. Simultaneously, muscular activity in the shoulders and forearms were recorded using ambulatory data loggers. Through combining the data concerning these work activities with, e.g. synchronised EMG data, statistics of muscular activity was calculated for the different work activities, see [9].

4 RESULTS

Using the synchronisation it was possible to link detailed physical exposure measures to specific work activities, which showed, for instance, an increased EMG activity in the trapezius muscles during value adding work activities (Figure 3). The work activity time consumption and the EMG analyses were first carried out separately for four hours of recordings. To identify the specific video-frame of the first EMG sample (see Chapter 2) took about 10 minutes. After that, the integrated analyses took approximately ten minutes in execution time for the Excel macro. Figure 2 illustrates a middle step where occurrences work activities and EMG data are set to a common time axis. In all, it required approximately half-an-hour to obtain diagrams as showed in Figure 3.

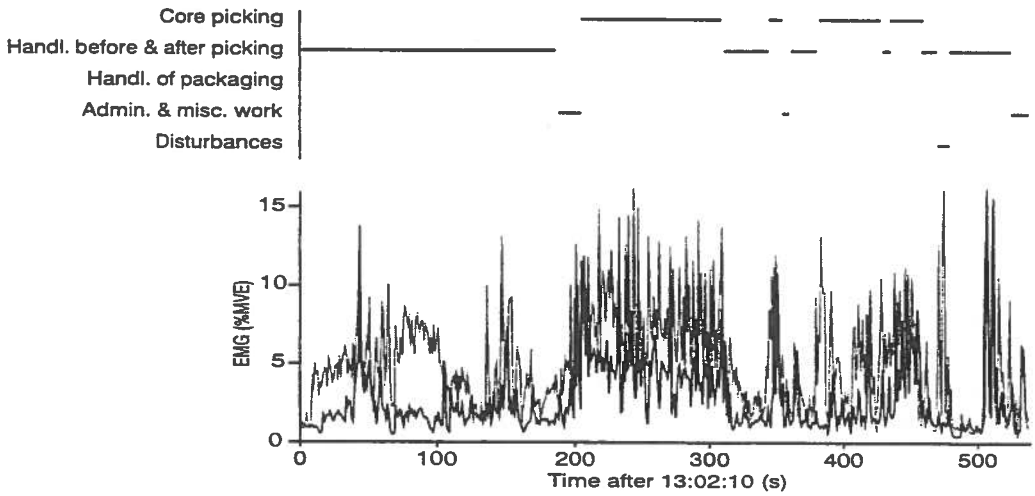

Figure 2. An example of occurrences of activities in the five activity groups and EMG (grey and black curves, left and right trapezius, respectively) from a material picker in work. The graph shows 9 minutes of the total measurement time of 4 hours.

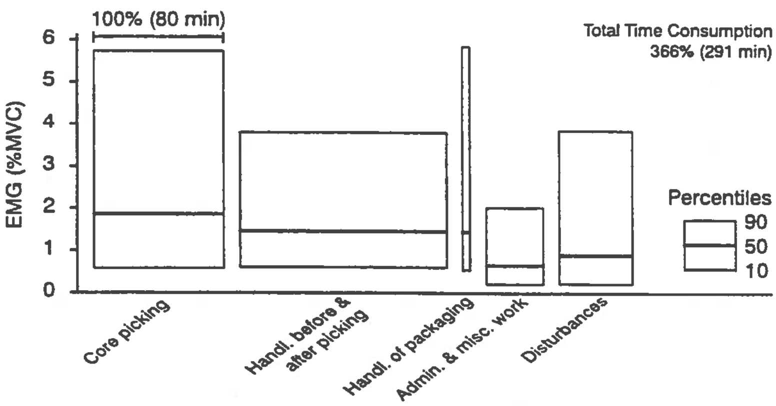

Figure 3. A diagram of an integrated analysis. The 10^{th}, 50^{th} and 90^{th} percentiles, of a picker's muscle activity of the right shoulder muscle, are marked for each of the five activity groups. The width of the each bar represents the time consumption of the activity group. The time for core picking - the value adding work – is set to 100%.

Over four hours of recordings including interruptions, e.g. exchange of accumulators and videotapes, and memory cards for the ambulatory data loggers, a synchronisation error of approximately 1 s was introduced. That is when synchronisation between the ambulatory data logger and the video recording just is executed in the beginning of the recording period. The time from the start of one activity to the start of an other was approximately 20 seconds in average, and simulations of synchronisation errors of ±1 second showed a low sensitivity to the synchronisation timing error on the derived measures of muscular activity in this data. For a shorter period without interruptions, synchronisation between the loggers and the video recordings was obtained at the time of one video frame (which corresponds to 0.04 seconds). This synchronisation could also be obtained over four hours of recordings if synchronisation between the data logger and the video recording is executed after every interruption.

5 DISCUSSION

By using the here presented method, detailed ergonomic information may be derived for various work activities that are relevant regarding productivity on a detailed sub-seconds time scale. Such data may, by time weighting, be used for estimating the "ergonomic cost" for the manufacturing in a specific production system. Moreover, these data may be used to predict the effect on physical exposure, by industrial interventions. Hence, traditional ergonomics, focusing on reducing individual peak loads [1], may instead be transformed into aspects of collective working and the exposure pattern.

A vital result from the case studies is that the synchronising procedure was sufficiently precise to allow different work activities to be assigned significantly different levels of physical exposure. It was concluded that the presented method was accurate enough to be a useful tool in, e.g., industrial interventions.

The human and technical aspects in Figure 1 were, in the diagram of Figure 3, represented by EMG and work task time consumption, respectively. Other diagrams (not shown, for space reasons), including for instance forward/back angle of the head in different work activities, were also obtained using the same procedure of synchronisation. These diagrams exemplify how a little extra effort, compared to separate analyses, may result in an integrated analysis. It was therefore concluded that the presented method supports the hypothesis that it is possible to amalgamate, in a synergetic way, human and technical aspects.

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