ON THE DEVELOPMENT OF A TIME-SENSITIVE ERGONOMICS EVALUATION METHOD

Berlin, C[1]

1. Department of Product- and Production Development, Division of Production Systems
Chalmers University of Technology, SE-412 96 Göteborg, Sweden
E-mail: cecilia.berlin@chalmers.se

As part of a research project with focus on ergonomics evaluation, a video-observation study of manual car assembly work was carried out. Rather than presenting the study results as hard data for further development, this paper discusses the advantages and disadvantages of using 'static' evaluation methods to rate and acknowledge accumulated physical load. In the study, RULA was used at five-second intervals as an unbiased discrete evaluation method with no specifically selected 'target' postures. The paper aims to discuss the scope of what a new time-sensitive method needs to accomplish, in order to be ready for the capabilities of dynamic human simulation.

Ergonomics, Evaluation Methods, Human Simulation, Dynamic Evaluation

1 Introduction

As computers have become more and more adept at rapid calculations, the capabilities of 3D visualization software have increased – notably so within the realm of animation and digital human modeling. Industry today focuses primarily on the evaluation of static postures, driven in part by the lack of suitable human performance analysis tools available for dynamic motion. (Chaffin, 2005). The entertainment industry has been a forerunner in producing convincing animated replications of human movement using concepts of geometric, physical and behavioural motion control methods to create acceptably realistic 'synthetic actors' (Magnenat-Thalmann & Thalmann, 1991). However, this advancement has not been as evident in ergonomic evaluation software. The digital evaluation tools that exist today are still hampered by the fact that there are virtually no 'dynamic' evaluation methods that can be implemented in them to accurately assess the effects of accumulated load, repetition, recuperation time, work variation etc. The push-effect of computer capabilities indicates a need for the development of continuous evaluation methods that can take such factors into consideration. Many validated evaluation methods, such as Rapid Upper Limb Assessment (RULA), are intended to be used as quick screening tools and are purposely carried out at a low level of precision according to McAtamney and Corlett (1993). This is related to the necessity of carefully selecting a few representative postures – otherwise, data input would simply take too much time.

With the capabilities of digital human modeling, it is possible to continuously record and analyze the flow of postures in a computer manikin performing a simulated work task. This opens up the possibility of dynamic assessment - if a tool continuously evaluates a movement sequence, selecting static work postures on the basis of the observer's ergonomic knowledge will no longer be needed, thereby making assessment available as a tool for people with other competences (compare with Laring, 2004).

However, these developments raise several questions. One of these is whether it is desirable and ethical to strive towards future digital modelling tools of such capacity that using them does not require extensive ergonomic knowledge. This would imply placing the assessment capability, but also the responsibility, in the hands of anyone. With this in mind, this paper will strive to highlight an interesting discussion point – do researchers and industry respectively wish to strive towards this?

2 Objectives

As clarification, the author would like to point out that the objective of this paper is not to address the actual results of the performed study, but rather to initiate a discussion regarding meaningfulness of developing a time-sensitive dynamic method.

There were several aims to the study itself; one was to examine the potential of RULA (McAtamney and Corlett, 1993) as a starting point for developing a new 'dynamic' method. In other words, the research team took a method generally used as a screening tool and used it at regularly spaced time intervals to achieve a continuous assessment. Possibly, this paper can be considered a critical look at the actual execution of the experiment and analysis phase.

3 Method

The research team decided to base the study on observation film material in a factory setting, rather than a simulated manikin equivalent, since the team desired a realistic sequence of work movements performed by various people.

3.1 Observation Setup

The study in question was an observation carried out in September 2006 at the Saab Automobile manufacturing plant in Trollhättan, Sweden. Two assembly line teams in the factory were selected for observation, based on the assessment of health monitoring personnel at the factory, who judged one assembly line (henceforth referred to as Line 1) to be ergonomically 'safe', while another assembly line (Line 2) was known for causing noticeable physical strain and discomfort, as reported to the corporate health care service. The observed workers within teams were selected on the proviso that they had been working at the same assembly line for at least the last six months. Aside from this, selection was made on the basis of consent, i.e. voluntary participation on the part of each worker.

Sixteen assembly workers were observed during whole-day work shifts. A team of four observers spent two days in the plant filming the workers. On day one, Line 1 was observed during the day shift and Line 2 on the evening shift, and day 2 vice versa. At each assembly line, the team of workers alternated between five or six specific tasks (referred to as 'stations') during the course of one shift. The distribution of observed workers is illustrated in Figure 1.

Typically, the team members changed stations with each other at intervals of 30 to 45 minutes. The worker at each station is responsible for assembling specific components on each car in succession, i.e. each station results in a repeated sequence of physical movements that starts over each time the worker begins on a new car. Therefore, the observers considered each station to consist of a number of 'work cycles' limited by the time spent at the station.

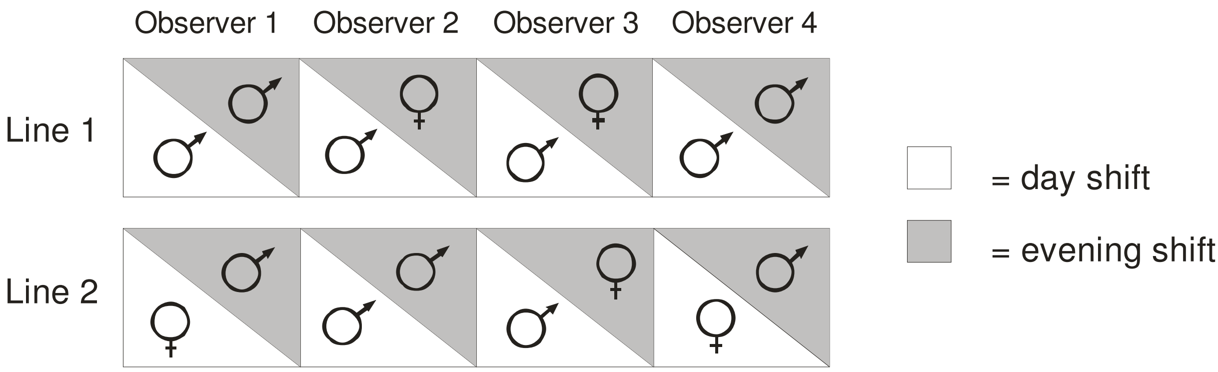
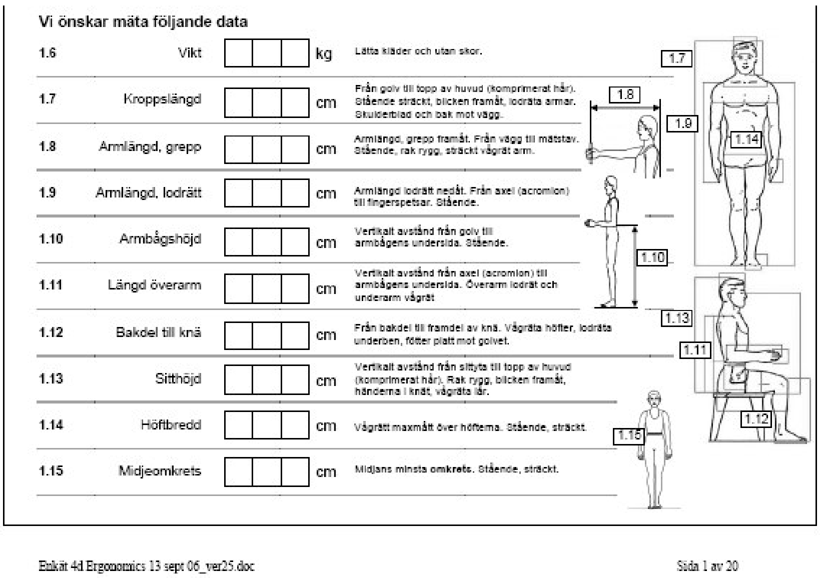


Figure 1 – the gender distribution of observed workers during the day and evening shifts at each of the two observed assembly lines.

All assembly work at the two selected lines was performed on a slowly moving conveyor belt that moved at a pace of 0.93 m/s.

3.2 Supplementary Questionnaires and Measurements

As a supplementary source of information, each observed worker was measured and asked to fill out a questionnaire concerning their physical health / injury history, level of physical activity outside of working hours, and psychosocial well-being at work. Each worker's relevant body dimensions were measured, according to the specifications on the first page of the Nordic Musculoskeletal Questionnaire (as developed by Kuorinka et al. 1987) – see figure 2 below. Equipment used included measuring tape, a weigh-scale for home use and round wooden rods (e.g. for measurement of grip-distance).



Vi önskar mäta följande data

1.6	Vikt	kg	Lätta kläder och utan skor.
1.7	Kroppslängd	cm	Från golv till topp av huvud (komprimerat hår). Stående sträckt, blicken framåt, lodräta armar. Skulderblad och bak mot vägg.
1.8	Armlängd, grepp	cm	Armlängd, grepp framåt. Från vägg till mätstav. Stående, rak rygg, sträckt vågrät arm.
1.9	Armlängd, lodrätt	cm	Armlängd lodrätt nedåt. Från axel (acromion) till fingerspetsar. Stående.
1.10	Armbågshöjd	cm	Vertikalt avstånd från golv till armbågens undersida. Stående.
1.11	Längd överarm	cm	Vertikalt avstånd från axel (acromion) till armbågens undersida. Överarm lodrät och underarm vågrät
1.12	Bakdel till knä	cm	Från bakdel till framdel av knä. Vågräta höfter, lodräta underben, fötter platt mot golvet.
1.13	Sitthöjd	cm	Vertikalt avstånd från sittyta till topp av huvud (komprimerat hår). Rak rygg, blicken framåt, händerna i knät, vågräta lår.
1.14	Höftbredd	cm	Vågrätt maxmått över höfterna. Stående, sträckt.
1.15	Midjeomkrets	cm	Midjans minsta omkrets. Stående, sträckt.

Enkät 4d Ergonomics 13 sept 06_ver25.doc

Sida 1 av 20

Figure 2 – Complimentary measurement specifications

3.3 Video Recording

The research team recorded five-minute samples of each assembly station (thereby capturing approximately 3 – 4 work cycles per filmed sequence, given that production was not disturbed). This resulted in approx 30-40 minutes of film for each observed individual, and was considered a representative sample of work movements during the course of one shift.

Since the workers rarely remained stationary, each researcher followed one individual worker at a time around the work area with a cordless video camera. It was sometimes not possible for the observer to maintain a full-figure picture of the worker at all times, usually due to a car obscuring the field of vision or the presence of factory equipment (or other workers) that prevented the observer from moving freely.

3.4 RULA ratings

The RULA method, as described by McAtamney and Corlett (1993) was used to assess the video material, with some exceptions to the rule – instead of selecting worst-case postures for analysis, RULA protocol was coded at five-second intervals for each film sample. Also, the calculation of the final grand score (the assessment of each posture, see McAtamney and Corlett 1993) for each posture was not the main goal; instead the research team focused on data input of the individual body part scores in Group A (Upper limbs) and Group B (trunk, neck and legs) rather than calculating a RULA Action Level (McAtamney and Corlett, 1993) for each posture.

When all the video data had been gathered, three-minute long film segments from each worker and work task were assessed by two research team members using RULA coding for film frames grabbed every five seconds. This was done regardless of whether extreme movements or postures occurred in between the frames, but was sometimes subject to the assessor's being able to see all body parts. This occasionally resulted in empty data fields or assessment of a posture in the near time vicinity (usually a few frames before or after the intended one).

4 Results

At the time that this paper was written, the results of the statistical treatment of the actual RULA data were still underway. However, the use of the method as an unbiased time-interval assessment yielded some practical difficulties, and in the sense that they can be regarded as results for this paper, they appeared as follows:

- The video material featured instances where parts of the worker's body was obscured, particularly the hands and wrists – this meant that the RULA assessor would not be able to judge the working posture, resulting in blank data input.
- The above result in turn led to inconsistencies among the two assessors, where one preferred to leave data fields blank while the other assessed proximal postures (a few seconds before or after the desired time-code) where the entire body was visible. This degraded the output data quality.
- The RULA coding was performed on average 36 times over a span of 3 minutes of film per work task, and performed on 16 x (5 or 6) film sequences. This was

very time-consuming work, but could not be automated as visual interpretation was required.

5 Analysis

As becomes evident from the list of results in chapter 4, the major problem with using RULA in the manner described is that the experiment becomes a rough replication of something that could be performed with much greater efficacy by a computer. Furthermore, for a human to code a visual image of a working posture takes time because of the need for visual interpretation of posture angles. This interpretation is riddled with uncertainties due to film ambiguities, blocked field of vision etc. A digital human model (a manikin) has the advantage of continuous data about joint angles, thereby reducing the uncertainties of assessing the relative postures. These facts easily account for the work being time-consuming. However, it also points toward the necessity of considering a computer as the 'user' of a new dynamic method, rather than a human assessor.
Data from a manikin's joints would probably also decrease the blank data and arbitrary frame-selection issues to a minimum.
Another consideration is the fact that certain extreme body positions can go missing in between the five-second intervals. The resolution of the discrete analysis can probably be increased if a computer does the calculating, but at the same time it raises a question; since RULA is usually intended to analyze extreme positions specifically, do the continuous results provide a principally 'wrong' assessment?
All in all, most of the difficulties which are described in chapters 4 and 5 are attributable to the fact that humans trying to perform a computer's task (such as RULA coding) are very limited in comparison. Also, the extra step of visual interpretation is apparently a hindrance for the development of a continuous method, which is why the use of a manikin becomes all the more advantageous, desirable and probably completely necessary for that purpose.

6 Discussion

Many interesting points of discussion arise from the execution aspects of the study. Some are concerned with the foreseeable obstacles in the near future, while others concern what this research will (or should) achieve in terms of greater efficacy and accuracy.
There are ethical considerations also – is it a desirable situation to develop an ergonomics evaluation tool that requires little or no ergonomic experience or knowledge to perform correctly? Much of the ergonomics competence can doubtlessly be integrated into a successful algorithm, but increases the assessor's dependency on the method being accurate.
The danger that this results in an 'inhuman' take on ergonomics, with possible overlooking of e.g. psychosocial or cognitive factors is possible. Therefore, that is an argument to keep ergonomics experts in the assessment process. At the same time, assessments based on the interpretation of individuals may be affected by corporate politics. A question that arises then is, can a computerized dynamic assessment of work eliminate the effects of personal interests and interpretations?
These two polarities – human expertise vs. computerized unbiased assessment – are something that needs to be discussed among researchers and industry. Also, the requirements on future ergonomics assessment need to be further defined: do industrial

applications require greater speed? Accuracy? Greater or less detail? More or less expertise?

In the end, it is important to realize that most established methods are meant for screening, thereby cutting down data input and analysis steps to a minimum. The greater speed of execution is achieved at the cost of low level of detail, but requires knowledge and discernment to be carried out correctly.

7 Conclusion

The author concludes that developing a time-sensitive ergonomics evaluation method based on RULA will involve a necessary shift of focus – instead of tailoring the method to a human assessor's judgment, a continuous dynamic method will have to be as independent as possible of interpretative issues. To limit visual ambiguities and save data input time, it becomes almost necessary to base all analysis on digital manikins, since they can supply continuous data feedback on necessary posture measurements.

Perhaps the most important thing to keep in mind is that the established screening methods (such as RULA) are meant to be carried out rapidly by humans, and therefore are inherently designed to minimize excessive data input and output, as well as effort involved in data recording and analysis. However, using such methods requires sufficient ergonomic knowledge to correctly recognize and select hazardous postures. A computer program does not need this mental workload consideration, and has the advantage of being able to perform 'unbiased' assessment of a series of posture data in a continuous stream. Therefore, designing a time-sensitive evaluation method may very well use elements of existing methods as rating principles, but should probably be tailored for use by an 'inhuman' assessor instead.

8 References

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