Database for Capability-Appropriate Workplace Design in Manufacturing Industry

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ABSTRACT

Due to demographic change, less younger workers are available and the amount of workers in general will decrease. In addition the average age of the working population will increase in western countries in the near future. With higher age absenteeism, especially due to musculoskeletal disorders, rises. Also the range of performance between individuals grows wider. But this is not true for all capabilities and not only for elderly workers. Therefore, a capability-appropriate workplace design is necessary to meet physical workplace demands in manufacturing industry and in order to preserve the workability of the workforce.

A large variety of capabilities is challenging in the context of workplace design in manufacturing industry. This high number of capabilities with a wide range of individual performance can be best captured and represented in a database. Therefore a suitable database will be developed, where relevant physical manufacturing capabilities are collected and processed for workplace designers. These work-related capabilities represent individual performance in different sections e.g. static working postures, manual materials handling and action forces. Based on this information, design solutions for a prospective capability-appropriate workplace design can be derived relative to the age structure of the manufacturing plant.

Keywords: eldery worker, work-related capabilities, database for workplace design

INTRODUCTION

A growing bottleneck in manufacturing and manpower planning in the automotive industry is a growing population of elderly workers in assembly. The change of the age-composition is a rising problem in Germany and the western countries. The average age of the working population will increase significantly (Deutsche Rentenversicherung, 2012). Beginning in 2017, approximately 40% of all workers will be over 50 years old (Statistisches Bundesamt, 2009). In addition, the number of the total population will shrink, and thus the proportion of people in the working age (15-66 years) decreases (ibid.). With higher age absenteeism, especially due to musculoskeletal disorders, rises (Meyer et al., 2011). The group of workers from 50 to 65 year causes thereby proportionately the largest part of the work loss. The majority of incapacity for production workers in the automotive industry is due to musculoskeletal disorders (ibid.). Musculoskeletal requirements are a major risk factor for production employees, who have a focus on physical work. The cause of disease often lies in the work itself, in addition to the natural biological aging.

Assembly work is characterized by physical stresses such as manual material handling and working in static awkward postures. Furthermore long-term and repetitive unilateral workloads pose a risk to the production workers. For longer periods, these risk factors can lead to functional limitations, degeneration and diseases of the musculoskeletal system, such as back pain or intervertebral disc problems and the cardiovascular system, e.g. Hypertension.

This results in enormous economic burden for society and for the company itself as well as the competitiveness of a company. Therefore a goal of a company should be to keep its employees healthy and workable as long as possible. A company's success depends on well-qualified, motivated and healthy employees (ENWHP, 2011). This gives the human factor in manufacturing industry an enormous role and the integration of human capabilities into the workplace design process. A company has to respond quickly to adapt workplaces to the needs of the employees and the change of the working population. An aging analysis at the company alone does not solve this problem. Workplace related capabilities of the employees should be recorded in detail, and then provided to the workplace designer. As part of a 3 years project "Development of age-robust workplaces based on age-differentiated capability data", funded by the German Research Foundation, a capability database for a prospective designing of capability-appropriate workplaces is developed. The concept of the database, which is intended to reflect the capabilities of workers of the German automotive industry, will be presented in detail below.

HUMAN FACTORS IN WORKPLACE DESIGN

The work system designing process is usually part of the product development process in every company. The product development process can be divided into definition, conceptualization, product- & process development, implementation & pre-series and series production (Bierwith, 2012). The human factor itself should be involved in a system design in a very early stage, beginning with the conceptualization phase and continuing through series production. The earlier in a product development process ergonomic demands are considered, the less economic costs will rise and a better quality of the product is generated (Landau et al., 2003).

The work system model contains a lot of processes for the design and construction of a whole work system. This includes, besides technological planning or human resources planning, the workplace design. Human factors plays an important role in a work system and therefore also in the workplace design process. The workplace design process after ergonomic principles in the design of work systems is described in DIN EN ISO 6385. There are six steps formulated in a workplace design process.

1. Formulation of goals
2. Analysis and assignment of functions
3. Conception of the design
4. Design of each item
5. Realization, implementation and validation
6. Evaluation

Human factors are considered in the first four steps of the process. This brings up the question “Which kind of human factors are important in a workplace design of assembly work?”. If we look closer at the Stress-Strain-Model of Rohmert (1984) the following characteristics of a person are important in work systems (Schlick et al., 2010):

- Property: such as gender, constitution, state of health
- Capabilities: acquired physical or mental characteristics through training or employment which enable a person to work
- Skills: acquired in learning and training processes that enable for simpler activities or processes
- Knowledge: stored in memory and continually updated knowledge, acquired through training and experience
- Qualification: set of knowledge, skills and capabilities

People have individual characteristics, some of these characteristics are changeable through short, middle or long

processes, and some are not changeable at all. But the most important thing is that the workplace matches the needs and performance prerequisites of the workforce. Especially for assembly work physical capabilities should be considered at workplaces.

WORK-RELATED PHYSICAL CAPABILITIES

Human capabilities can be separated into cognitive, physical, sensory, and social capabilities. Capabilities in ergonomics are defined as the potential to perform an action or to produce a physical or mental work outcome (WIAD, 2013).

The variety of capabilities and performance levels grows wider with higher age. Not all capabilities decrease with higher age, there must be also positive changes mentioned. Capabilities, which increase with age are mostly cognitive and social capabilities like experience, practical judgment and the sense of responsibility. However, in older age groups the ability to compensate for stress decreases. Overall, heterogeneity increases with age (Nelson and Dannefer, 1992). This means that the needs become multifarious and the capabilities of workers become even more diverse (Johnson, 2010). Physical capabilities do not generally increase with age (Rademacher et al., 2013). There two capabilities, where statistical significant differences between younger and older workers exist: manual material handling and working in awkward postures (trunk bent forward > 60 °) (ibid.). These findings need to be considered in an ergonomic workplace design.

The focus on this study will be only mainly physical capabilities, which are needed in production systems. In order to detect relevant physical capabilities, a deduction between job demands in assembly work and existing work-related assessments was made. The following categories of physical capabilities were set, which are of interest for the database:

- Body Postures (e.g. standing, kneeling, arms over head)
- Locomotion (e.g. walking)
- Action forces (e.g. finger-/ hand-forces)
- Manual Material Handling (e.g. lifting, carrying , pulling, pushing of loads)
- Hand-Coordination (e.g. finger pinch)

APPROACH FOR CAPABILITY-APPROPRIATE WORKPLACE DESIGN

A first approach towards capability-appropriate workplace design was made by a big survey from Rademacher et al. 2013. This survey provided a comprehensive data pool of capability data from a large scientific investigation with a German automotive manufacturer. Through this survey the physical capabilities from more than 100 assembly workers were analyzed.

Through ergonomics workplace assessment of more than 200 workplaces in automotive industry relevant work-related requirements and physical stress were assessed with the Ergonomic Assembly Worksheet (EAWS) (Landau et al., 2008; Rademacher et al., 2008). Afterwards physical requirements have been identified, which are common and critical activities in vehicle assembly. Adapted to these requirements, a special work-related physical capability assessment was developed by Rademacher et al. (2013), which is based on Isernhagen (1988) "Functional Capacity Evaluation Isernhagen Work Systems" (IWS FCE). The following work-related capabilities derive for the database:

- Walking, Crouching, Kneeling, Standing
- Working in awkward postures; trunk bent forward 20°-60° and more than 60°
- Right and Left Arm on shoulder level (> 90°)
- Right and Left Arm above head level (> 110°)
- Right and Left hand-forces (till 40 N)

- Pro- and Supination of the right and left forearm
- manual material handling (5kg - ≥ 25kg)

The data is rated on a five step scale from none to severe limitations. This rating of the capabilities is encoded for the database to a certain exposure time. It is transferred for the workplace designer into percentage of a full shift, frequency and duration.

The orthopedic functional assessment was based on a standardized screening for musculoskeletal disorders (screening of the musculoskeletal system). It is a functional assessment to determine possible range of motion and reflexes as well as to obtain information about pain and disorders of the subjects. Additionally questionnaires about the physical disorders as well as a self-reflection of the work ability were surveyed.

To assess the physical disorders Rademacher et al. (2013) used a standardized questionnaire, which is based on the Body Part Discomfort Scale of Corlett & Bishop (1976) and the Nordic Questionnaire (Kuorinka et al., 1987). This questionnaire provides essential information of disorders of different joints, back and muscles, and the localization of these symptoms as well as their severity.

For the self-assessment of the workability of the study participants, the short version of the Workability Index questionnaire (WAI, Tuomi et al., 1998) was used. The WAI contains seven items and supplies at the end of a total score, which allows to classify the current work ability of the subjects (Ilmarinen & Temple, 2002).

Furthermore there are many capability profiles from a German car manufacturer availibe for the database, which provide data about various capabilities.

DEVELOPING HUMAN A CAPABILITY DATABASE TO SUPPORT WORKPLACE DESIGNERS

The database is to be maintained and enhanced by automotive companies. This high number of capabilities with a wide range of individual performance can be best captured and represented in a database (Tenneti, 2012). Furthermore such a database is necessary to systematize and process data to provide capability data for workplace designers. The database will be an analysis tool for work-related physical capabilities or limitations in relation to the age structure of the workers. This will help to give the workplace designer detailed information of the different needs and the differentiated work-related capabilities of the workforce.

Users

The end user of the database will be a workplace designer, who can use this database as a planning tool during the product development process. The workplace designer should be able to derive important design approaches from the work-related capabilities. The aim of workplace design is to create workable and tolerable working conditions (Kirchner, 1972). The capability database offers workplace designers important information on the ability and tolerability in relation to the respective workforce (Müglich et al., 2004). On the ability level workplace designer receive information on various capacities and their characteristics, e.g. which forces can be applied by workers and which body dimensions are taken into account in the design. Regarding the tolerability of the work the workplace designer receives information by encoding the capabilities and respectively limitations to a certain exposure time and by a consideration of age-related physiological changes. Tolerability means that work can be performed over a longer period of time without any complaints or diseases occurring to the worker. They also receive information as to which capabilities are critical in workplace design, by focusing on limitations with a high amount of workers. But they receive the information of great potentials of workers, too. In relation to the age of the workers, they can observe how the capabilities are developing with an increasing age.

Another important user group for the database are occupational physicians as they make the capability assessment of

the workers and thus provide the capability data for the database. Firstly, all work-related physical capabilities should be recorded in detail and provided with a detailed assessment. Only individual capability assessments/ profiles provide detailed information about capabilities. The ability level is evaluated by occupational physicians, through diagnosis and assessment of the performance level of the workers and their documentation in the database (ibid.). The focus is only on the workers and their individual performance. The capability assessment can be documented directly in the database.

Requirements

The aim of the database is to create a prospective design solution for a capability-appropriate workplace design in assembly lines in the automotive industry. Prospective means, in this context, to give a worker an opportunity for a personal development (Ulich, 2005). Furthermore the database should have a good usability and it should be easy to use for practical application during the planning process.

Through a stakeholder analysis and an interview with a workplace designer it became evident that the amount of workers and their performance level concerning workload intensity and duration in relation to each job demand would be of interest. A combination of multiple capabilities is also from importance. For example, it is important for a workplace designer to know how many workers have limitations regarding manual material handling, how many people have limitations on a trunk bending forward, how many workers have no trouble with both requirements, or how many workers have difficulties with both requirements. On the one hand it is helpful to know which amount of workers have limitations and are not able to work under certain job demands. Thus, a request of a critical value was mentioned, which give the workplace designer information about critical job demands. On the other hand, it could also be helpful to see where there are big potentials of workers. That means that just a small amount of people with limitations cannot perform certain job demands. Furthermore, it is helpful to learn how the capabilities develop in the life span relating to the age structure of the workforce. In addition, instructions and guidelines concerning anthropometric data, forces and range of motion are needed for workplace measures.

These requirements lead to the following questions:

- What physical capabilities and general physiological changes must be considered for workplace design?
- What are the potentials of worker or especially of elderly worker?
- What are the major limitations?
- Which anthropometric data, forces and range of motion must be considered for workplace design

Database-Model

The database model (see Figure 1) shows which data contained in the capability database, where they come from and how they will be processed and presented.

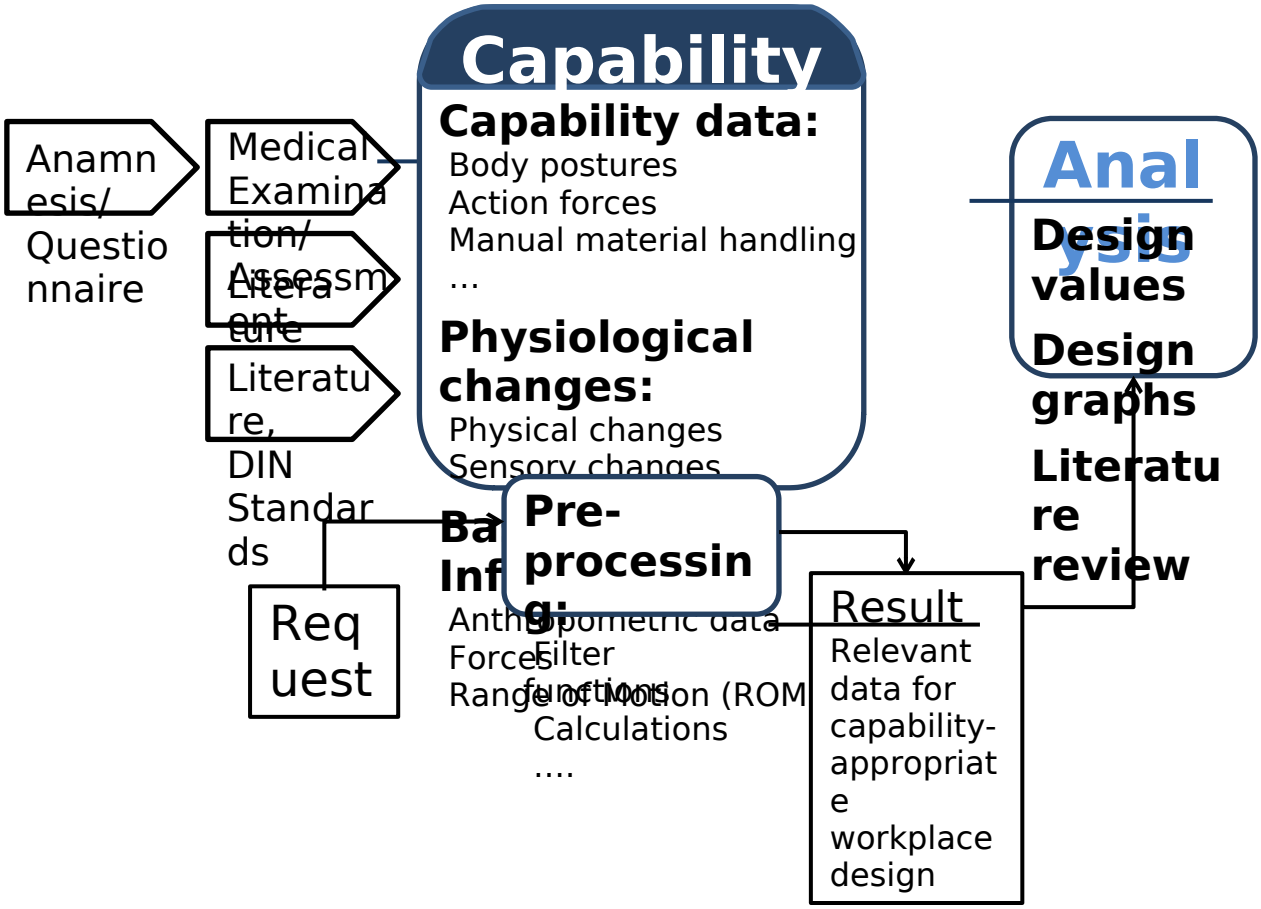

Figure 1. Database Model

The core of the database is the physical capability data. The work-related physical capability data will be delivered by occupational physicians through an evaluation of the functional capability. The capability evaluation also includes questionnaires or an anamnesis about the current discomfort of the worker. A subjective assessment of the worker is recommended as a supplement to the objective measurements to make a reliable statement about the individual performance (Schian et al., 2004). Furthermore, the occupational physician carries out a medical examination in order to complete the holistic view on the capability level. These diagnoses and investigation data are important, because they contain information about the relationship between physical limitations and ability to work. The capability data is connected with information about the person, which provides age, gender and the associated workplace.

In relation to each capability, information about physiological characteristics and development will be given from relevant literature. This information will help to make workplace designer aware which physiological changes can influence the capabilities of the workers in order to provide a healthy workforce.

Workplace engineering also includes information on forces, body dimensions and range of motion. These data will be also available in the database, which will be derived from literature or DIN standards. Especially in the context of age, the decrease in muscle strength and range of motion must be considered (Biermann & Weißmantel, 2003; Lang, 1991; Wakula et al., 2009).

Depending on which information the workplace designer in his workplace creation process needs, he can set a specific filter on the dataset. A filter can be set for example on a specific age group, a specific workplace, a specific or a combination on capabilities, or the exposure time. Each filter contains a statistical analysis of the data. The data output includes instructions and guidelines especially for a prospective capability oriented workplace design and other health-promoting hints. The output of the database will deliver important information in different

visualizations e.g. different graphs, percentage or amount of people. Outputs which should be considered for the workplace designing are highlighted. Furthermore the end user receives information about physiological changes.

CONCLUSIONS

There is a need for activities to be taken due to the changing age structure in Germany and thus the changing age structure in companies. Companies have to deal with high absenteeism of older workers and therefore the rising economic costs. This requires a systematic and long-term approach to be able to respond adequately to the effects of the age structure shift. The collected capability data from a previous project with the topic "Age-differentiated work systems" is now transferred into a database, so that they provide prospective information about workplace design in production areas of automotive companies. The capability database is currently being developed and tested in a pilot project with a large German automobile manufacturer.

This project will face the detected problems Johnson et al. (2010) discuses concerning existing databases that deal with capabilities of people. These problems are namely:

- Lack of collection of different capabilities
- No specific studies for assessing capabilities correctly
- Collected data are from a non-representative population

The database is intended to provide prospective information for designing capability-appropriate workplaces and is therefore primarily designed for workplace designers and ergonomists. Furthermore, this database could be interesting also for Health and Safety and general health managers of automotive companies to derive the outputs from the database measures in the relevant field.

Moreover, it would substantially support the planning process to collect data from workplace assessments and provide them in the database. This would help workplace designer to make a matching between the current workplace situation and the amount of workers who can operate at these workplaces.

Furthermore, if information about the changing age structure of a company would be accessible, a projection of the development of capabilities with respect to the expected age structure would be possible. A projection of a changing average age includes information about how many new hires are needed and how many people how will retire. This information must be accessible for a prediction of the development of capabilities.

Later, in order to make definite statements about developments of capabilities, it is important to expand the dataset continuously. A further aim is to extend the database with capability data from other German automotive companies in order to create a representative data pool. By using the database from more than one company, the data base may also be expanded. This would help to provide longitudinal sectional observations on the development of capabilities of workers.

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