Christopher Marc Schlick
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Age-Differentiated Work Systems

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Age-Differentiated Work Systems: Introduction and Overview to a Six-Year Research Program in Germany

Christopher M. Schlick, Ekkehart Frieling and Jürgen Wegge

The disproportionate aging of the populations in many nations around the world is a unique occurrence in the history of humankind. It has a major impact on the working population, and thus on the age structures in companies. This is because such aging of the population usually leads to disproportionate aging of employees in organizations, while ever fewer young people are available in the employment/work sector. Furthermore, the percentage of individuals of working age declines in the population as a whole.

Fertility and mortality have a major influence on the developments referred to as demographic change. The fertility rate states the average number of live births per woman aged between 15 and 44. It is also referred to as the birth rate. The mortality rate expresses the number of deaths in relation to the overall population. A decrease in fertility leads to a declining percentage of younger people in the population as a whole and in the working population, while declining mortality is associated with growth in the group of older people and older employees. Life expectancy is often used in place of the mortality rate as a measurement of mortality. The development is inversely proportional—a decrease in the mortality rate is associated with higher life expectancy.

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In the light of demographic change, it is becoming increasingly important to develop and use the potential of older employees. In the future, fostering, preserving, and making appropriate use of the knowledge, skills and abilities of older employees will be a major objective for any company or firm. The focus will be on topics such as age-specific motivation and skill development as well as designing tasks, equipment and tools ergonomically, and establishing appropriate working hours for older and aging employees.

Demographic Developments and Their Effects on the Working Population

Demographic Developments in Germany

It is expected that the current population of just under 82.4 million in Germany will decrease to between 65 and 75 million by 2050 (Eisenmenger et al. 2006).

The fertility rate in Germany has declined almost continuously since peaking during the baby boom of the mid-1960s. In fact, the mortality rate has exceeded the birth rate since the beginning of the 1970s. In 2009, life expectancy in Germany was 77.8 years for men and 82.8 years for women, slightly above the EU average. Compared with 1993, life expectancy at birth has increased by five years for men and by 3.5 years for women (European Commission 2010).

The development of life expectancy and the decline in fertility for the period from 1995 to 2050 will be almost diametrically opposed linear processes. This means that there will be a long-term change in the age structure in Germany. The number of people over 65 will rise from 16 million in 2008 to over 22 million in 2030 to around 23 million by 2050. At that point in time, every third inhabitant of Germany will be 65 or older (Eisenmenger et al. 2006).

If these demographic developments continue, fewer people will live in Germany in the future, and the percentage of older people in the population as a whole and in the working population will increase significantly. The dependency ratio, which expresses the ratio of people of working age to those of non-working age, is an important indicator of the development of the working population. Since the 1960s, the age dependency ratio has constantly increased. Forecasts show that it will increase further in the coming decades. This means that the number of workers in Germany will decrease from 41.9 million in 2000 to 29.6 million in 2050 (Cologne Institute for Economic Research 2005). A rapidly declining number of people of working age can be expected as early as 2020. This will have a particularly strong impact on the number of young skilled workers available. Increasing “aging of society” will have the following effects on the age structure of the employment and working sector: By 2020, the average age of people of working age will have already risen by 2.2 years in Germany. While the highest percentage of labor potential consisted of people aged between 30 and 45 in 2000, 50–60 year-olds will make up the largest group in 2020. The aging process described in this book will primarily occur during the next 10–15 years.

International Demographic Developments

In contrast to the population in Germany, the global population will continue to grow in the future. The latter, which currently stands at seven billion, is forecast to rise to 9.6 billion by 2050 (DSW 2011). Almost all of this population growth will occur in developing countries. Asia is the continent where this development will be most evident. Huge growth can be expected in India in particular. It is expected that India will have a population of over 1.6 billion by 2050, thus replacing China as the country with the largest population (DSW 2011).

Figure 1 shows the fertility rate as a major factor in population growth for Europe, the United States and Asia. The countries with the highest fertility rates worldwide are in Africa and western Asia (United Nations 2004). Unlike other developed regions, the population aging process in the U.S. is not as pronounced. This is due to a higher fertility rate and slightly lower life expectancy—particularly in comparison with European countries. According to a recent report of the European Commission (2010), the fertility rate in Europe has been below 1.5 children per woman since 1995.

Most of the countries with a very high life expectancy in global terms are found in Europe (United Nations 2004, see Fig. 2). In 2009, life expectancy at birth in EU countries was 76.4 years for men and 82.4 years for women in 2009. In the U.S., life expectancy at birth was 75.9 years for women and 80.9 years for men in 2011. Life expectancy is thus in the top third worldwide. Life expectancy at birth in Asia was 68.9 years from 2005 to 2010.

The United Nations forecasts that fertility and mortality rates in the developing regions will evolve similarly to those of the industrialized nations, albeit at a slightly later stage (see Figs. 1 and 2) so that all countries and regions worldwide will be affected by population aging in the end (United Nations 2004).

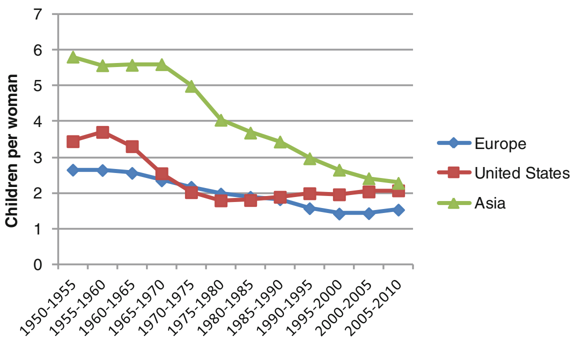

Fig. 1 Development of the fertility rate between 1950 and 2010 in Europe, the United States and Asia. Data according to United Nations Department of Economic and Social Affairs, Population Division (2011). World Population Prospects: The 2010 Revision

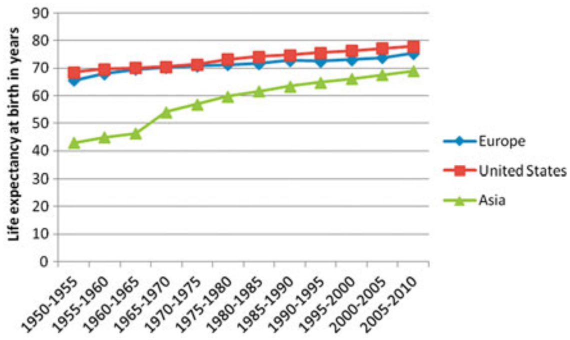

Fig. 2 Development of the life expectancy at birth between 1950 and 2010 in Europe, the United States and Asia. Data according to United Nations, Department of Economic and Social Affairs, Population Division (2011). World Population Prospects: The 2010 Revision

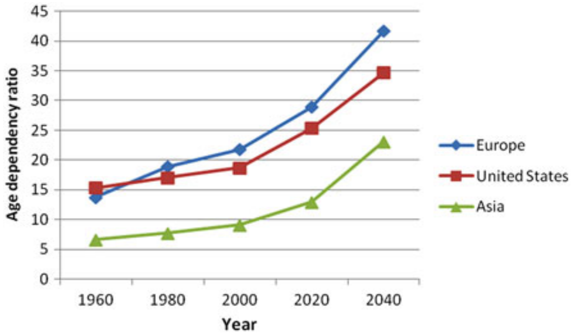

Fig. 3 Development of the age dependency ratio (ratio of population aged 65+ per 100 population 15–64) between 1960 and 2040 in Europe, the United States and Asia. Data according to United Nations, Department of Economic and Social Affairs, Population Division (2011). World Population Prospects: The 2010 Revision

The development of age distribution among the global population in the past decades shows that the percentage of younger people in the population as a whole is declining (the share of those aged between 0 and 14 will decrease by 10 % between 2000 and 2050), while the group of older people is constantly growing (the share of people over 65 will increase to 15.9 % between 2000 and 2050).

These developments have an impact on the previously mentioned dependency ratio (Fig. 3). An increase in the age dependency ratio can be observed not only in developed regions such as Europe and the U.S., but also—albeit at a lower level—in developing regions like Asia. In 2040, only slightly more than two people from the group of people of working age will provide for one person from the group of people over 65 (United Nations 2011). A high percentage of children among the overall population leads to a high dependency ratio in developing countries, while the increasing number of old people causes this ratio to rise in developed regions.

Implications for Hiring Persons, Designing Human Work, and Conducting Research in the Field of Ergonomics

Forecasts indicate that the population aging process in industrialized nations will accelerate during the first decades of the 21st century. This means that there will be ever fewer younger workers in the employment system, while older workers will become increasingly important for companies' economic and social development. Simultaneously, there is a trend for people to retire early. The combination of both developments means that companies have significant difficulties in meeting their needs for qualified, motivated and capable persons. In the future, many companies will face the challenge of fostering, preserving and making even more effective use of the knowledge, skills and abilities of their increasingly older employees under the existing competitive market conditions.

In this context, the fact that demographic change is a global phenomenon cannot be ignored. While the aging process will initially accelerate in the industrialized nations, in the long-term it will be felt worldwide.

In geographical terms, the regionally diverging parameters and effects of demographic change should not be discounted either. In other words, the population aging process must be viewed differently for different regions. Regional economic strength and job supply have an impact on these developments. For example, the trend is for young people to migrate from structurally weak regions. The average age of the population rises, while the number of potential employees declines. As a result, there is a greater focus on older employees in the recruitment of new staff.

Apart from the challenge facing companies of fostering, preserving and making appropriate use of the knowledge, skills and abilities of older employees, the complementary task of improving the quality of working life of younger persons through preventative, prospective work design must also be taken into account. Successfully designing work so that it is suited to older or aging employees requires knowledge of (1) the employee and the development of his/her organismic, perceptive, cognitive, sensorimotor and motivational "sub-systems" and knowledge of the effects of stress and strain resulting from (2) specific work tasks, (3) the equipment and tools used at work and (4) the work environment in terms of human performance and reliability. The following questions arise as a direct result:

- How should tasks be structured in an age/aging-appropriate way so that they support the use of individual optimization and compensation strategies as regards performance and health?
- What principles and rules must be used when designing work equipment and tools so that they can be used effectively, efficiently, safely, and with an appropriate level of strain, by older and younger users?
- How should the work environment be designed so that the intensity of environmental factors does not cause harm and, in the case of older people who may not be able to withstand as much stress, does not lead to unacceptable levels of strain?
- How can companies deploy employees appropriately in terms of age and aging in order to keep them in the work systems longer and promote intergenerational teamwork?

The aim of the six-year Priority Program 1184—Age-differentiated Work Systems was to answer these questions.

Age-Differentiated Work Systems

The Priority Program 1184—Age-differentiated Work Systems was launched by a pluridisciplinary team of researchers and funded by the German Research Foundation (DFG). The program began in fall 2005 and was set up for a six-year period. During these six years, a total of 19 universities and non-university research institutions from all over the Federal Republic of Germany were involved in the program. The research findings of 17 project teams are presented in this edited volume of the same name in condensed form. Project teams from different work-related disciplines, such as occupational psychology and ergonomics, worked on different yet interrelated relevant research tasks.

The priority program's research objective was to develop models and methods that companies could use to design and optimize their work systems and offer their employees age/aging-appropriate working and learning conditions. The aim was that the models and methods would have a sound theoretical basis in terms of their scientific derivation and form of explanation. Furthermore, they were to be empirically sound with regard to the effectiveness of the interventions based on them. Over 40 laboratory experiments involving 2,000 participants and 50 field studies involving over 25,000 employees were conducted under the priority program. The idea was that the findings from this research would help companies detect and avoid errors in their assessment of the capabilities and motivation of older workers and create objectively good working conditions.

In order to achieve the main research objective, there was continuous coordination and regular discussions between the individual projects. Findings were presented and discussed, and cross-project and cross-disciplinary cooperation networks were established at regular meetings. Apart from discussion and cooperation with research groups/initiatives at the national level, as well as with various organizations (e.g., automobile manufacturing, fiscal authorities, financial services, and schools), a large number of activities was undertaken to make the concepts, methods and results of the priority program also available on an international level. These included writing journal articles (e.g., for the Journal of Applied Psychology, Journal of Motor Behavior, and Journal of Industrial Ergonomics), publishing special issues [Occupational Ergonomics (2010); Zeitschrift für Arbeitswissenschaft (2006, 2010); Zeitschrift für Personalpsychologie (2009); Wirtschaftspsychologie (2008); Journal of Managerial Psychology (in press)], and conducting sessions at international conferences [(e.g., the International Congress of Psychology 2008; European Association of Work and Organizational Psychology 2007, 2009, 2011; Conference on Applied Human Factors and Ergonomics 2010; International Symposium of Human Factors in Organizational Design and Management 2011; and World Congress of the International Ergonomics Association 2012]. Over the six-year program period, the wide range of the research areas combined with various theoretical and methodological approaches improved the generalizability of the research findings and their transfer to and application in corporate practice.

The priority program focused on the design and evaluation of age-differentiated work systems. In the following section, the concepts "age-differentiation" and "work system" will be explained in greater detail as well as in relation to each other and discussed in the context of the objectives of the priority program.

Conceptual Framework

Since the system approach is a general one, the work system concept does not initially imply a particular level for viewing work processes—in other words, it can refer equally to an individual job or to an entire company. However, it generally refers to the former level and to the operation and movement of tools and at machines involved in a job. Depending on the question posed, the observed structure of the work system can be differentiated in various ways. However, it always includes a person and a task as a minimum requirement (Rohmert 1983). In general, a work system can be described using the following elements: person, task, equipment and objects. Furthermore, physical and social environmental factors must be considered. A work system can also be linked with other systems through input–output relationships. This provides a structured scheme for describing most work structures systematically.

The priority program viewed the work system elements listed above as part of a whole and analyzed their interdependencies. In addition, the program observed the diverse interactions between individuals, focusing on factors such as strategies for regulating emotions, motivation and actions. Person-centered structuring of age-differentiated work systems implies that the opportunities and challenges for an individual's capabilities and motivation to change with age are considered. At first sight, the demand for age-differentiated work systems is highly ambivalent, since it tends to imply that older people in particular need "different" working conditions from younger people due to changing performance and strain profiles. "Different" often means tasks with greater levels of mechanization or automation in terms of ergonomics or tasks that place lower physical, perceptive or cognitive demands on workers. In this context, the term "age-differentiated work systems" could imply a certain stigmatization of old age due to the general differentiation that it makes between the performance and well-being of younger and older workers. Obviously, this should be rigorously avoided in practice, firstly because objective findings partly contradict this assumption and secondly because it lowers the acceptance of interventions derived from methodology. For example, more recent research shows that there is no systematic relationship between a person's calendar age and his/her work performance (Ng and Feldman 2008; Wegge et al. 2008). In recent years, there have been significant changes in the explanatory and forecasting models that deal with notions of aging people's performance and strain. While earlier models presumed that the only changes would be for the worse (deficit models), that is, they assumed that a constant process of decline starts from the age of 28 (Naegle 2004), the compensation or competence model is now used to describe changes in older adults. These models assume that behavior, experience and strategies can compensate for the changes caused by age and that older adults have a command of a qualitatively more differentiated performance spectrum than younger people (Astor et al. 2006; Ng and Feldman 2008; Martin and Kliegel 2010). The assumption of a “differential age”, which assumes different developments in human functions during the aging process, has increasingly replaced the hypotheses derived from the deficit model. Information-processing subsystems are assumed to have multiple resources that can be used differently in term of quality. Aging processes are understood differentially and in a far more complex manner in terms of their development (Czaja 1997; Brandstädter 2007). In this way, differing inter-individual aging processes can be described and explained. The extent of the changes can vary. In addition, they can occur at different times and proceed in various directions (Birren and Schaie 2006; Maintz 2002). Hence, it cannot be assumed that performance generally declines with increasing age, but rather that changes occur in mental and physical abilities. On one hand, this variability is caused by the fact that performance differs both among individuals, that is, between different people (inter-individually), and in a single person (intra-individually). For example, it can depend on a person’s level of training or current state of health. On the other hand, increasing variability, particularly in older people, also results from the growing risk of deteriorating health. In practice, it is often difficult to differentiate between “normal” (primary) and “pathological” (secondary) aging.

An initial conclusion from the above observations is that the rules for designing work systems cannot apply universally, but rather must take intra- and inter-individual differences into account. Further analysis shows that while certain measures for designing work systems can have a significant positive impact on younger workers, the effects on older workers can differ in terms of effectiveness and even in terms of direction. However, ergonomic working conditions specially developed for older workers can often be of benefit to younger workers too, and can help improve well-being. In this context, one speaks of a design-for-all approach.

The priority program researchers examined selected work system elements in terms of both their age-differentiated impact and their interactions. In this context, the focus was not on “engineered” age-differentiated design, but on the type and extent of the impact of work-related factors on changes in performance and motivation. The idea was that appropriate work design measures should be used to adapt technical, organizational and social conditions to people so that companies can provide harmless, feasible, bearable and unimpaired working conditions and make individual development possible (Luczak and Volpert 1987). Various empirical studies have shown that it is not feasible to have standardized “optimum” work structures and processes for all workers (Zink 1978; Triebe 1980, 1981). In this respect, the research on work systems was age-differentiated, for example when the objective was to answer questions about distributing tasks among workers in terms of stress and strain (such as which forms of work are particularly suited to younger people and older workers respectively) or when the research involved the age-differentiated design of work processes and equipment (such as which organizational, technical and social conditions support younger and older workers' performance, motivation, and health). The findings can be used to adapt existing work structures and processes retroactively to the requirements of human work. This involves a correcting or corrective type of work design. The findings can also be applied when designing new (differential) work systems. The aim of this preventative strategy is to avoid damage and impairment to health from the outset and to take ergonomic, technical, organizational, and economic requirements into account in the planning and design phase (see Ulich 2005).

The priority program's analysis of a work system's individual elements and their interaction was age-differentiated, and in some cases it also used other criteria such as skills (analysis level). This part of the priority program involved an individual approach that can be used to develop design measures that can prevent existing or future work-related declines in performance and impairments to health. The individual findings and solutions were subsequently summarized in the work design process as an overall solution (synthesis). At the synthesis level, the research projects derived criteria, principles and rules for designing work structures and processes. This derivation followed the preventative work design strategy. It can be described as aging-appropriate work design that takes work-relevant skills and capabilities and the resulting ergonomic requirements into account. Aging employees are not the only ones affected by such measures; designing work systems in terms of prevention can help to forestall a loss of work and employment capacity among younger workers too. The aim is to maintain and further develop employees' perceptive, motor, motivational, emotional and social-communicative skills throughout their entire working life.

The overall objective was that the priority program's findings would provide a valid, methodologically sound foundation for the integrated design of aging-appropriate work systems. Such systems are age-differentiated or age-specific where economic, technical or organizational constraints and limitations prevent the implementation of ergonomic working conditions for all groups of employees, where workers' performance has already been curtailed, or where improvements in efficiency, effectiveness, and occupational health and safety only result from the inclusion of age-specific factors. However, cohort effects must be taken into account when applying the priority program's findings to real-life work systems. These effects are closely related to the analytical methods used (Birren and Schaie 2006; Schaie and Hertzog 1983). In the priority program, both longitudinal and cross-sectional studies were conducted; in the latter, cultural and social differences between the cohorts deserve special consideration when interpreting the findings.

Designing age-differentiated work systems—taking into account the work system's individual elements—not only involves hardware and software ergonomics, but the design of tasks and specific work time models, mixed age groups, teamwork, and aspects concerning age-specific motivation and competence development. The focus here is on differential work design that goes beyond an inclusion of inter-individual differences and stipulates the simultaneous availability of various structures that individual workers can choose from. In terms of age-differentiated work system design, this implies the individualization of tasks, equipment and compensation strategies—provided that the design measures affect younger and older workers differently. The priority program's primary research topic involved the question of what type and scope of age-differentiation the design measures would require. To what extent and in what form should work systems be designed in terms of age-differentiation? Which design measures are particularly suited to younger and older workers respectively? What are the limits of age-differentiated design and when should it be supplemented or replaced with "age-robust" design in the sense of "design for all"? The individual chapters in this book address the debate over age-differentiated and aging-appropriate design of work systems, answer the questions raised at various levels of observation, and consolidate the findings in the form of "lessons learned".

Structure of the Priority Program

Design and intervention strategies at the micro- and macro-ergonomic level are essential to the development of sustainable concepts for age-differentiated work systems in companies. As a result, the 18 subprojects integrated over the course of the program period utilized both of these levels.

The focus of the subprojects ranged from economic analyses of productivity among older employees in different sectors to analyses of stress and strain at the workplace level to observations of the impact of working in cold conditions on older workers' thermoregulation. The subprojects' research topics and questions were grouped based on the level model by Luczak and Volpert (1987). Seven levels were differentiated:

1. Sectors and Value Networks
2. Enterprises and Companies
3. Cooperation in Work Groups
4. Holistic Activities and Work Forms
5. Tasks and Workplaces
6. Sensorimotor Control of Tools
7. Autonomous Organismic Systems and the Work Environment

In some cases, the projects could clearly be assigned to a particular level, while in others they addressed the overlaps or junctions between two levels.

1. *Sectors and Value Networks*

Productivity, employability, and corporate age structure mutually influence each other. At the first level, these interdependencies were examined from an overarching economic perspective on different sectors and the underlying value networks. Among other things, the effects of different staff age structures on productivity combined with various types of work systems, human resources measures, and corporate structures were estimated empirically on the basis of micro-econometric procedures (see chapter Age-Differentiated Work Systems Enhance Productivity and Retention of Old Employees, Zwick et al.).

2. *Enterprises and Companies*

The focus at the second level was on researching how workers could be deployed in companies in an age-appropriate way in order to keep them in the business processes for a longer time.

Under certain circumstances, the strain of an identical stress on older workers is greater than that on younger workers. The design of working hours plays a particular role here. The second level focused on the impact of different working-time models on aging workers in companies. It took into account various corporate variables such as different shift systems and approaches to work design, for example as regards the division of labor. Both short-term and long-term effects at the corporate and individual level were examined.

Furthermore, the analyses concentrated on sensitizing senior managers and on developing relevant aging-appropriate human resources deployment strategies, taking into account age-appropriate performance and stress. Staff qualifications and the way that human resources are deployed are major variables in age-appropriate work system optimization (see chapters Development and Evaluation of Working-Time Models for the Ageing Workforce: Lessons Learned from the KRONOS Research Project, Knauth et al.; Effects of an Ageing Workforce on the Performance of Assembly Systems, Zülch et al.).

3. *Cooperation in Work Groups*

When examining the deployment of humans in work systems, the different abilities and skills must be taken into account. Equally, social and communication needs must be considered in terms of organizational aspects of cooperative work. Social needs and individual performance are closely connected. Examples include situations when team work or group work leads to a positive working atmosphere, thus simplifying cooperation processes or improving performance. The priority program concentrated on cooperation between people in work groups. The focus was on age diversity in the work groups and its impact on performance and health (see chapter Age Diversity and Team Effectiveness, Ries et al.).

4. *Holistic Activities and Work Forms*

In order to be able to design work systems in an age-differentiated way, the person-centered design process should begin with an investigation of which strategies the workers for whom the system is being designed use to regulate their emotions, motivation and actions. Hence, the fourth level involved subprojects that investigated, among other things, the effects of emotion regulation on health. However, the extent to which workers are prepared to exploit their abilities depends on their motivation. Motivation, which is also referred to as drive regulation, is physiologically determined by the stimulation level of organs or organ systems. Psychologically, it is determined by attitudes to performance and motives such as needs, interests, intentions or convictions (Schlick et al. 2010). During the priority program, age differences in drive regulation were examined in terms of career-related motives, job satisfaction, emotional resilience and the use of control strategies in pursuing career goals.

At the fourth level, the research on emotion and drive regulation was extended to include findings on action regulation. Psychological gerontology shows that the individual level of function can be maintained if available resources are deployed effectively using selection, optimization and compensation (SOC) action strategies (Baltes and Baltes 1990). Another important theoretical development is the Socioemotional Selectivity Theory (SST, Carstensen 2006) which predicts that older workers de-prioritize goals related to growth and advancement and instead emphasize social and affective values. For the priority program, the focus was not only on examining the link between SOC strategies and the health and performance of older workers but also on the age-related differences in work motivation and control strategies while pursuing career goals (see chapters Age Differences in Motivation and Stress at Work, Hertel et al.; Age-Related Differences in the Emotion Regulation of Teachers in the Classroom, Philipp and Schüpbach; and Successful Aging Strategies in Nursing: The Example of Selective Optimization with Compensation, Müller et al.).

5. *Tasks and Workplaces*

Tasks and the conditions under which they are carried out influence capabilities and motivation. At the task and workplace levels, the priority program primarily examined the influence on capabilities. This was supplemented by analyses of physical and mental stress and strain. In this context, the research projects focused on the aging-appropriate design of work systems in automobile assembly and on system design in the realm of vehicle driving. In the former area, the effects of "Takt"-driven, short-cycle assembly work on employees was examined, with age taken into account. Specific load situations were analyzed. Combined with the skills profiles, these situations justify age-differentiated work design in the relevant production systems. The research projects aimed to provide fundamental insights into a balanced, age-differentiated load profile and the strain related to it in order to maintain older workers' capacity for employment and work. The specific research on driving included an examination of the effects of complex visual-motoric dual tasks, such as driving with an additional secondary task, in terms of age-related differences. Here the aim was to provide recommendations for aging-appropriate design of traffic situations and technical aids. In addition, recommendations can be derived for the optimum design of driving training for older drivers (see chapters Assembly Tasks in the Automotive Industry: A Challenge for Older Employees, Frieling et al.; Capability Related Stress Analysis to Support Design of Work Systems, Rademacher et al.; Field Study of Age-Critical Assembly Processes in the Automotive Industry, Börner et al.; Age-Related Differences in Critical Driving Situations: The Influence of Dual-Task Situations, S-R Compatibility and Driving Expertise, Aschersleben et al.; and Age-Related Changes of Neural Control Processes and their Significance for Driving Performance, Hahn et al.).