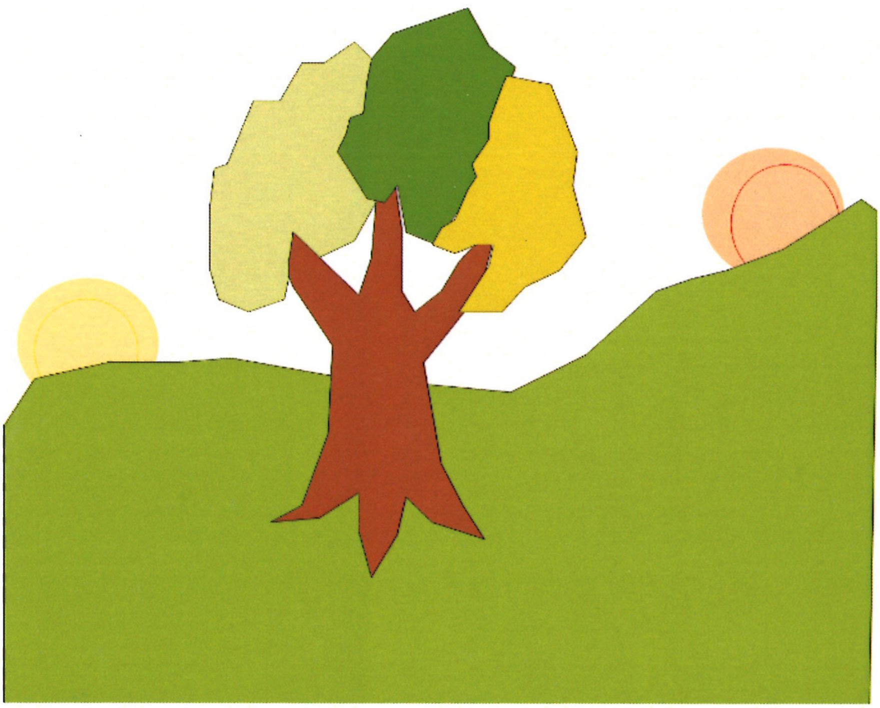
JYVÄSKYLÄ STUDIES IN EDUCATION, PSYCHOLOGY AND SOCIAL RESEARCH
336

Isto Ruoppila, Pekka Huuhtanen,
Jorma Seitsamo, Juhani Ilmarinen

Age-Related Changes of the Work Ability Construct and its Relation to Cognitive Functioning in the Older Worker

A 16-Year Follow-Up Study



JYVÄSKYLÄN YLIOPISTO

JYVÄSKYLÄ STUDIES IN EDUCATION, PSYCHOLOGY AND SOCIAL RESEARCH 336

Isto Ruoppila, Pekka Huuhtanen,
Jorma Seitsamo, Juhani Ilmarinen

Age-Related Changes of the Work Ability Construct and its Relation to Cognitive Functioning in the Older Worker

A 16-Year Follow-Up Study

The Finnish Institute of Occupational Health, Helsinki, Finland

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2008

Age-Related Changes of the Work Ability Construct and its Relation to Cognitive Functioning in the Older Worker

A 16-Year Follow-Up Study

JYVÄSKYLÄ STUDIES IN EDUCATION, PSYCHOLOGY AND SOCIAL RESEARCH 336

Isto Ruoppila, Pekka Huuhtanen,
Jorma Seitsamo, Juhani Ilmarinen

Age-Related Changes of the Work Ability Construct and its Relation to Cognitive Functioning in the Older Worker

A 16-Year Follow-Up Study

The Finnish Institute of Occupational Health, Helsinki, Finland

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2008

Editors
Tapani Korhonen
Department of Psychology, University of Jyväskylä
Pekka Olsbo, Marja-Leena Harjuniemi
Publishing Unit, University Library of Jyväskylä

URN:ISBN:978-951-39-8242-3
ISBN 978-951-39-8242-3 (PDF)
ISSN 0075-4625

ISBN 978-951-39-3127-8
ISSN 0075-4625

Jyväskylä University Printing House, Jyväskylä 2008

ABSTRACT

Ruoppila, Isto, Huuhtanen, Pekka, Seitsamo, Jorma and Ilmarinen, Juhani
Age-Related Changes of the Work Ability Construct and its Relation to Cognitive Functioning in the Older Worker: A 16-year Follow-up Study
Jyväskylä: University of Jyväskylä, 2008, 97 p.
(Jyväskylä Studies in Education, Psychology and Social Research,
ISSN 0075-4625; 336)
ISBN 978-951-39-3127-8
Yhteenveto: Työkykyindeksin yhteydet kognitiivisiin toimintoihin ikääntyvillä työntekijöillä

The aim was to find out age-related changes in the Work Ability Index (WAI) and cognitive functions as well as their cross-sectional and longitudinal relations. The data are based on the follow-up study of municipal employees which begun in 1981 when subjects' (N=6257) age-range varied between 44 and 58 years. The first dataset consists of those who replied to the questionnaires in 1981-1997, and remained at work until 1992 (n=717). The second consists of those who attended the laboratory tests and were occupationally active in 1981-1985 (n=68). It was expected that both the WAI and cognitive functions decrease during the 11 years, the changes being greater in the WAI than in cognitive functions, and that the changes in the WAI are more strongly correlated with self-rated than with measured cognitive functions. The methods included the WAI and five tests from the WAIS (Similarities, Block Design, Digit Symbol, Digit Span, and Picture Completion). Also self-ratings concerning reaction capacity, memory and sense of comprehension were used. The WAI decreased with ageing from 1981 to 1992, among men and women, and in all types of work. Also WAIS scores decreased from 1985 to 1997 with the exception of the Digit Span. The WAIS scores were highest in the mental work group. The important replicated finding was that the WAI began to decline in late middle-age, but the decrease of WAIS scores started later and was clearly slower among those who were still working and especially doing mental work. The objective cognitive changes supported weakly the decline hypothesis. Self-rated cognitive functions partly improved during the follow-up and correlated higher with WAI than the test scores. The findings showed a mutual interaction between measured cognitive functioning and WAI as predicted. The cross-lagged correlations between WAI and SCF were lower than expected. The physical and mixed types of work were detrimental for cognitive functioning and WAI. To keep cognitive functioning and the WAI high, the work should include characteristics typical of mental work.

Keywords: work ability index, cognitive functioning, WAIS, ageing workers, gender, content of work, longitudinal study

PREFACE

In 2003 Dr., Jeffrey W. Elias, National Institute of Aging (NIA), New York, USA and Editor-in-Chief of the Experimental Aging Research, Dean´s Office UC Davis Medical School, Sacramento, California solicited an expert opinion on area of work ability and cognitive aging - a new theme of interest for NIA. We decided to accept this challenging request on the basis of our expertise based on cross-sectional and longitudinal studies on many fields of blue- and white-collar jobs and professions on work ability in Finland, and especially in the Finnish Institute of Occupational Health (FIOH), Helsinki. We would like to thank Dr., Elias and NIA for showing interest in work ability and also given financial support for this effort.

Because follow-up studies on work ability and cognitive aging have been rather rare we decided to strengthen the cognitive aging aspect with a broad literature review. Professor (emer.) Isto Ruoppila, Department of Psychology, University of Jyväskylä, Finland kindly joined the FIOH team and prepared a literature review on cognitive aging from the viewpoint of work life. The work ability part is written by research professor Pekka Huuhtanen, Dr., Jorma Seitsamo and professor Juhani Ilmarinen from the FIOH, who have actively participated in the development and research of the work ability since 1980s.

We would like to express our sincere thanks to Dr., Frank Winn, Medical College of Georgia, US, for his critical and constructive comments on the manuscript. We would like to take this opportunity to recognize his valuable efforts in making the work ability concept better known in the US. We are also grateful to Professors Ulla Kinnunen and Clas-Håkan Nygård for their insightful comments that helped us clarify our thinking as well as our text. Moreover, we would like to thank Michael Freeman, PhD, Department of Languages, University of Jyväskylä, and Alice Lehtinen, English Language Editor, for checking the language of our manuscript and Annikki Smolander, Project Assistant, for the editing of the text.

Finally, we would like to thank the Jyväskylä Studies in Education, Psychology and Social Research for given a high level platform for this report. The Department of Psychology has contributed the publication of this text.

In Helsinki and Jyväskylä
January 2008

The Authors

CONTENTS

1 INTRODUCTION

The ageing of the workforce is a global phenomenon. Almost one third of the work force in the European Union will be 50-64 years old in 2025 (Ilmarinen 1999, 2006). The average age at exit from work life was 60.8 years in 2002, and the 10 new member states show a similar trend. At the same time pension reforms in several countries aim at encouraging older workers to stay on at work for 2–3 years longer. In 2005 only 42.3 % of 55 to 64-year olds in the European Union work force were still actively participating in work life. A target employment rate of 50 % for older workers has been set for the year 2010, and 59 % for the year 2025 (European Commission, 2003). However, the employment rates of older workers differ markedly between the European countries; for example in 2005 the highest rate was registered in Sweden (69.4 %) and the lowest in Belgium (26.7 %). The average employment rates of 55 to 64-year-old workers in the USA (60.8 %) and Japan (63.9 %) were higher than in the EU, but the declining trend in older worker employment from 1997 to 2002, as in Japan (2.6 percentage units), creates serious concerns for the future.

Work life has undergone substantial changes due to new technologies and globalisation. Although surveys show that physical demands continue to exist in 20-25 % of occupations (Ilmarinen 2002, 2006), mental and social demands at work have risen continuously (Ilmarinen 2006, NIOSH 2002, Rantanen 2001). Cognitive functions thus play an increasing role in work life. Contrary to the decline in physical functions, the changes in cognitive functions during ageing are different, and depend on the specific cognitive function (Chapter 3).

The complexity involved in attaining a better fit between ageing and work is illustrated in the Figure 1. The matrix describes the problems, solutions and goals from the perspective of the individual worker, the organization and the society. The vertical level stresses the responsibility of keeping older workers in work life should be shared between these three groups. On the horizontal level the dimensions of recognizing problems, choosing solutions and setting goals depict the fact that solutions can be found and objectives can be brought into focus from the point of view of the individual, organization or society. The horizontal level thus emphasizes action. These actions can be called "Age Management".

The key words of the matrix have been chosen on the basis of data drawn from several intervention studies and from the practical experience gained in the FinnAge Programme from 1990–1996 (Ilmarinen and Louhevaara, 1999). The main message of the matrix is that this complex situation, as a whole, the fitting of ageing and work is possible. To obtain the greatest benefit from actions on the level of society (lower right box), the goals of the individual and organization should be set first. Although all three actors (individual, organization, society) are important, organizations play a key role. They have the potential and power to design and adjust work and work processes for older workers.

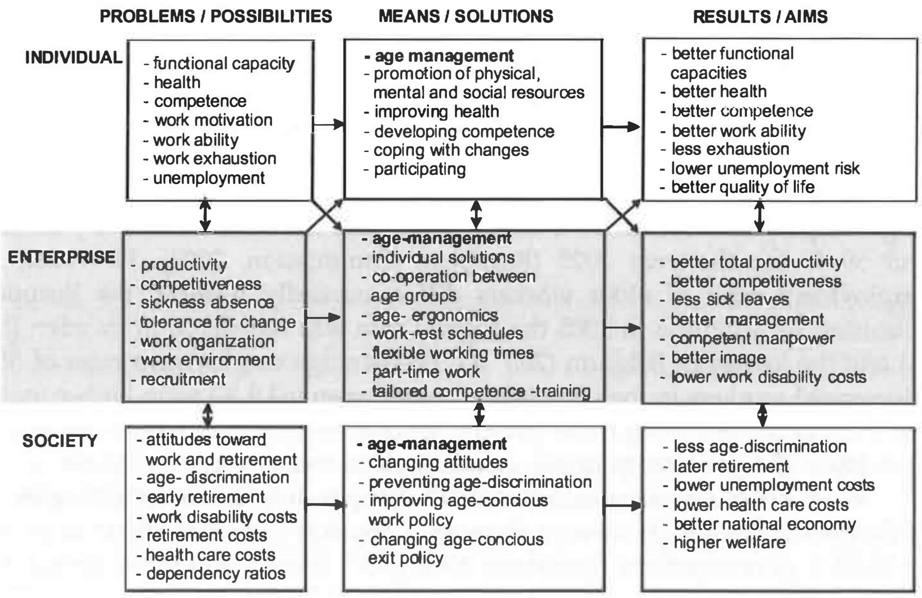


FIGURE 1 Ageing and work - a challenge for everyone

Although there are very few research findings on age-related cognitive changes as they relate to work ability, we can draw some conclusions from the data that are available. Studies that have examined work ability and age related cognitive changes have noted that both factors load on the individual's job requirements, particularly as they relate to skills necessary for the job and those skills that must be increased or improved for continued functioning in the job (Tuomi et al., 1998). Age-related changes in the cognitive domain and work ability vary interindividually. Thus, while some persons will have a high cognitive capacity as well as high work ability until old age, some will experience light declines and some heavy losses which will affect work disability. These changes differ on their onset age, magnitude, and also, direction, but for the majority, the general trend is great stability in cognitive functioning until the age 70.

It seems that the work ability begins to decrease earlier than the cognitive functioning, commencing at age 52 to 58 years (Ilmarinen et al., 1997). The steepest increase of poor work ability was found in physically demanding jobs, and a more gently sloping trend was typical in mental work and among women in mixed work. It may be that the present work life emphasizes speed and attention for both blue-collar but also white-collar workers. In Finnish jobs and professions, at least, pressure at work has clearly increased during the last ten years.

However, both cognitive functions and work ability can be affected positively by many different kinds of successful interventions. Especially fruitful in this context may be the model by Baltes and Baltes (1990) of selective optimization with compensation. For example, Salthouse (1997) has noted, that older workers can compensate for age-related losses, such as the slowing of information processing and psychomotor reactions by their long work experience and anticipation of future situations. Of special note are the findings reported by Willis and Schaie (1994) indicating that the cognitive domain can be improved by intervention. Similarly Louhevaara et al. (2003) have demonstrated that work ability, as assessed by the Work Ability Index (WAI), can also be affected by various activities, particularly employee participation. It was further noted that the content of interventions should cover all four crucial dimensions of the WAI (i.e., work environment, work community, and the health and occupational competence of the individual).

Because work ability index is based largely on self-ratings made to questions on the WAI, the results may correlate higher with other self ratings scales, concerning an individual's metacognitions, than with investigator measured cognitive functions. While this would be a logical prediction, based in part on the similarity of methods, we cannot ignore the possibility that other self ratings also share variance with these measures, e.g., the individual's own age-ratings (e.g. how old he or she feels to be).

The age-mixture in the work community is also important. Not only absolute ages but also relative age differences between individuals can be important factors affecting on possible age bias or discrimination in opportunities for development (Maurer et al., 2003).

Very few longitudinal studies have examined both age-related changes in the cognitive domain and work ability, with representative samples. Recent multidisciplinary (occupational physiology, psychology, medicine, epidemiology and biostatistics) longitudinal research on age-related changes in work ability and cognitive functions may add to the knowledge base. Thus, the aim of this study is to identify the age-related changes, measured by the WAI and cognitive functions, and reciprocical relationships during an 11-year project using a cross-lagged design in different types of physical, mental, and mixed work environments. The study questions are derived from the previously provided literature review.

In this study, the changes in the work ability index (WAI), measured cognitive functions (MCF), and self-rated cognitive functions (SCF) are analyzed as are the longitudinal reciprocal associations between WAI, MCF, and SCF.

The following study questions were addressed:

Question 1. How do cognitive functions and the Work Ability Index (WAI) change during ageing? Are the changes different a) between men and women and b) among different types of work?

On the basis of described age-related changes in the WAI and cognitive functions, it is expected that the changes should be similar in directions, but that larger changes should be found for the WAI than found for measures of crystallized intelligence since the WAI is closer to those changes noted in fluid intelligence.

Question 2. What is the association between WAI and both measured (MCF) and self-rated (SCF) cognitive functions? Is the association similar a) between genders and b) among different types of work?

We hypothesize that the WAI is more related to the self-rated cognitive functions than to experimenter measured cognitive functions already because of the common method variance, and that the WAI, MCF and SCF are moderately positively correlated.

Question 3. How do the relationship between WAI and SCF change over time, and how are gender and type of work associated to these changes?

We hypothesize that during the ageing process both the WAI and the cognitive processes interact with each other, meaning that the WAI predicts the later measured cognitive functions and vice versa.

The purpose of this report is to review the relationship between work ability and ageing, paying particular attention to how work ability relates to cognitive ageing. First, the work ability construct will be introduced (Chapter 2). Work ability and its measurement has been a major topic of interest at the Finnish Institute of Occupational Health since the 1980s. A Work Ability Index (WAI) was constructed for the follow-up studies of 6500 municipal employees over 45 years of age, carried out in 1981, 1985, 1992 and 1997 (Tuomi et al. 1997). After discussing the work ability construct we will provide wide review of cognitive ageing and work ability (Chapter 3). The next chapter introduces the threatening and resource factors of work ability during ageing (Chapter 4) followed by the results of the longitudinal study concerning work ability and cognitive functions (Chapter 5). The findings of the longitudinal study as well as the information of other chapters will be discussed together in Chapter 6. The last chapter (chapter 7) consists of conclusions based on this study.

2 THE WORK ABILITY CONCEPT DEVELOPMENT

2.1 The milestones of the work ability concept development.

The milestones in developing the work ability concept development by FIOH were the following:

1981 - 1997	Follow up study on ageing of municipal employees (at baseline 45-58 years)
1981 - 1985	Work Ability Index (WAI), validation and changes during 4 years
1981 - 1992	Work Ability Index (WAI), explaining factors of its changes during 11-years
1989	Agreement between employees and employers for a comprehensive Promotion of Work Ability
1990 - 1996	Developing and testing the Promotion concept of Work Ability (PWA), Action Programme on FinnAge - Respect for the Ageing
1993 -	Translation, testing and using of WAI in other languages (25 languages in 2006)
1993 -	Training and implementing of WAI for occupational health services in Finland
1998 -	Supporting the international implementation and evaluation of WAI and PWA, organising international symposia by ICOH and IEA aging committees
2000 -	Health2000 Survey with representative data of WAI from Finland
2003 -	New dimensions of work ability, development of Work ability-house based on Health2000 study.

2.2 The Work Ability Index (WAI)

In the 1980s work ability was a new concept that had not previously been defined or studied. At that time, the concepts related to work ability concerned diseases and disability rather than health and functional capacity. Scientific research on perceived health, functional capacity and longevity provided some guidelines for searching for indicators that would remain valid throughout the whole life course and would also measure the positive dimensions of work ability. Compared with work performance or working capacity the work ability related the human resources more broadly with work life.

The conceptual background of work ability was based on the stress-strain concept (Rutenfranz 1981) and a balance-model, where individual resources correspond to job demands in a healthy and safe way. The interaction between the characteristics of individuals and their work suggest that work ability can be influenced through both human resources and by developing adjustments to work.

The Work Ability Index was developed through questionnaires (Tuomi et al. 1985, Tuomi et al. 1991) and its validity was tested with clinical examinations (Eskelinen et al. 1991) and correlation analyses. The Work Ability Index (WAI) was defined conceptually as follows: "How good the worker is at present and in the near future, and how able he/she is to work with respect to the demands of the job and his/her health and mental resources?" (Ilmarinen, 1993)

The data from the first questionnaire, administered to 6500 subjects in 1981, was used in developing the WAI. The analyses and calculations on how to weight and classify the items were made using statistics. How the selected variables were related and should be integrated in the Index was studied through extrapolations by cross-sectional analyses and statistical tests. The final selection was made by correlation and reliability analyses (Tuomi et al. 1985). Self assessment of WAI related well with the clinical assessment of work ability at the group level (Eskelinen et al. 1991).

The items of the Work Ability Index (WAI) are given in Table 1, and WAI questionnaire in Appendix 1.

The score depicts the worker's own concept of his/her work ability. Level of work ability and the objectives of any measures deemed necessary are classified as follows:

Score	work ability	objective of measures
7-27	poor	restore work ability
28-36	moderate	improve work ability
37-43	good	support work ability
44-49	excellent	maintain work ability

TABLE 1 Items of the Work Ability Index

	Item	Nr. of questions	Scores
1	current work ability compared with lifetime best	1	0 to 10
2	work ability in relation to the demands of the job	2	2 to 10 (score weighted according to dominating work content)
3	number of current diseases diagnosed by a physician (list of 51 diseases)	1	1 to 7
4	estimated work impairment due to diseases	1	1 to 6
5	sick leave during the past year (12 months)	1	1 to 5
6	own prognosis of work ability two years from now	1	1,4 or 7
7	mental resources (note: item 7 refers to the worker's life in general, both at work and during leisure time)	3	1 to 4
	Total score		7 to 49

The main reason for assessing work ability is to identify what type of actions is needed to prevent its decline. Therefore, the WAI guidelines booklet includes a list of actions and their follow-up (Tuomi et al. 1998).

Some validity and reliability characteristics of WAI will be given below. The predictive power of WAI for work disability and mortality is given in Figure 2 and the predictive validity of different items of WAI in Table 2. The reliability of the items at three measurement points are given in Table 3. The validity and reliability of WAI are described in detail by Ilmarinen and Tuomi (2004).

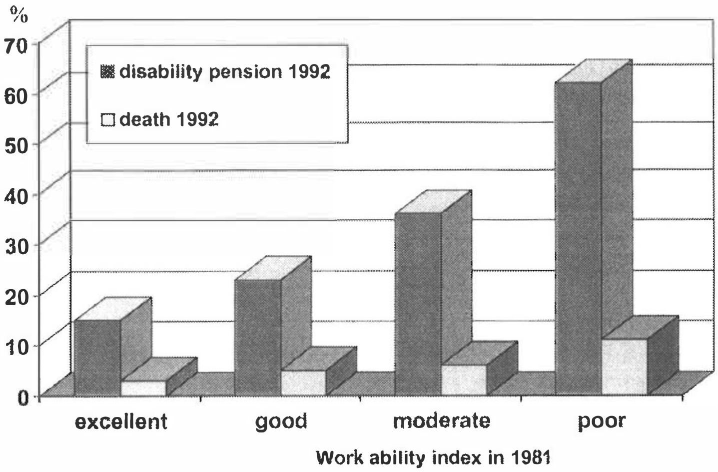


FIGURE 2 The predictive power of WAI for work disability and mortality

According to Figure 2, WAI correctly predicted the future development of work ability. Of those with a poor WAI in 1981 about 60% were awarded a work disability pension 11 years later (Tuomi et al. 1997).

WAI and all its items also predicted retirement due to work disability and mortality between the years 1981-1985, 1985-1992 and 1992-1997.

The highest predictive values were found in the items: (i) own prognosis of work ability two years from now, (ii) work ability in relation to the demands of the job, (iii) estimated work impairment due to diseases, and (iv) current work ability compared with lifetime best (Table 2).

The assessment of the reliability of WAI indicated that Cronbach's alpha was 0.83 at each measurement time. The following items had the strongest effect on the reliability and showed the highest internal consistency: (i) current work ability compared with lifetime best, (ii) work ability in relation to the demands of the job, (iii) estimated work impairment due to diseases, and (iv) mental resources (Table 3).

TABLE 2 The items of the Work Ability Index, and their predictive validity during the three follow-up periods of subjects who worked full-time throughout the follow-up in 1981-85, 1985-92 and 1992-98 versus deceased and disabled workers in the respective periods. Chi-square values and significance ($p<0.001$ ***,p <0.05 ** of the frequency tests).

Items of Work Ability Index	1981-85 n = 5202	1985-92 n =2399	1992-97 n = 248
Own prognosis of work ability two years from now	766.4***	492.3***	66.2***
Estimated work impairment due to diseases	722.9***	303.8***	52.0***
Current work ability compared with life-time best	682.8***	449.5***	42.4***
Work ability in relation to the demands of the job	649.3***	449.8***	72.3***
Sick leave during the past year (12 months)	372.8***	282.1***	25.0***
Number of current diseases diagnosed by a physician	250.6***	293.6***	37.1 ***
Mental resources	164.0***	189.6***	12.4*

TABLE 3 Reliability of items covered by the Work Ability Index (WAI). The subjects were 51-year-old full-time workers in 1981 (n=5251), 55-year-old full-time workers in 1985 (n= 3408), and 61 years old in 1992 (n=927). Reliability coefficient= Cronbach's alpha.

	Values of Cronbach's alpha		
	1981	1985	1992
Work Ability Index	0.83	0.83	0.83
Value of Cronbach's alpha in each of the following items of WAI is excluded[a]			
Current work ability compared with life-time best	0.81	0.77	0.76
Work ability in relation to the demands of the job	0.81	0.79	0.75
Number of current diseases diagnosed by a physician	0.83	0.81	0.80
Estimated work impairment due to diseases	0.81	0.78	0.77
Sick leave during the past year (12 months)	0.85	0.81	0.79
Own prognosis of work ability two years from now	0.83	0.79	0.83
Mental resources	0.85	0.81	0.78

[a]A low alpha value after excluding an item means that the item had a strong effect on the index and, correspondingly, a high alpha value after excluding an item means that the item had a weak effect on the index.

2.3 Factors influencing the Work Ability Index

The results of the 4-year and 11-year follow-up studies revealed the factors that influence work ability. According to the 4-year follow-up of municipal employees, three sets of work-related factors significantly reduced a person's work ability during ageing: (i) excessive physical demands of the job, (ii) heavy work and hazardous work environment, and (iii) poorly organized work (Ilmarinen et al. 1991). It was noted that a poor work organization had the same negative effect as the two other traditional risk factors of health and work ability.

The 11-year follow-up verified the earlier findings, but also demonstrated the role of individual factors on work ability. A logistic regression model indicated that factors related to management, ergonomics and life-style explained both the improvement (Table 4) and the decline (Table 5) in work ability. These factors were prominent among both men and women, and independent of type of job and age from 47 to 58 years.

TABLE 4 Logistic regression analysis explaining the improvement of the WAI[1] in 1981-92. Odds ratios (OR) and 95% confidence intervals (95%CI) of work and life-style factors. (n=555)

Factor	OR	95% CI
Less repetitive movements	2.1	1.0-3.4
v.s. No decrease	1.0	
More satisfaction with supervisor's attitudes	3,6	1.8-7.2
v.s. No increase	1.0	
More vigorous physical exercise in leisure time[1]	1.8	1.0-3.5
v.s. No increase	1.0	

[1]WAI score had improved by at least three points from 1981 to 1992

TABLE 5 Logistic regression analysis explaining the decline of the WAI[1] in 1981-1992. Odds ratios (OR) and 95% confidence intervals (95%CI) of work and life-style factors (n=805)

Factor	OR	95% CI
More standing in one place	1.7	1.0-2.9
v.s. No increase	1.0	
Less satisfaction with work stations[2]	1.6	1.0-2.6
v.s. No decrease	1.0	
Less recognition and esteem at work	2.4	1.4-4.3
v.s. No decrease	1.0	
Less vigorous physical exercise in leisure time[1`]	1.8	1.2-2.8
v.s. No decrease	1.0	

[1]WAI score had declined at least three points from 1981 to 1992.

Based on the results of the 11-year follow-up study, the concept of work ability promotion was created by FIOH and tested during the FinnAge - Respect for the Ageing Programme in 1990-1996 in several work organisations in Finland.

2.4 The latest construction of work ability

Although the conceptual background of work ability remains valid today, the changes that have taken place in work life prompt the need to clarify and develop the work ability concept. Recent research has clarified the new dimensions of work ability. The latest construct to illustrate these dimensions is the work ability "house" (Figure 3.) (Ilmarinen and Tuomi 2004).

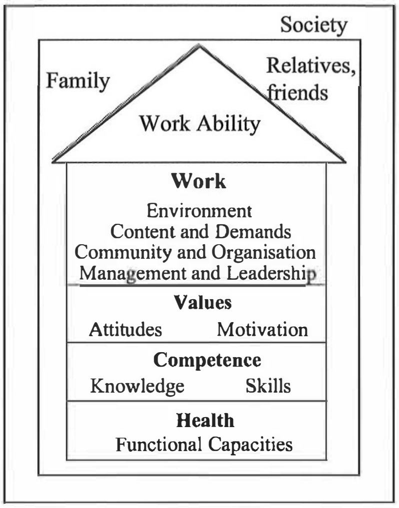


FIGURE 3 The latest dimensions of work ability

The work ability "house" has four floors. The three lowest floors depict human resources, and the 4th floor covers all the dimensions of work. It is important to note, that, although work ability is assessed as an individual trait, the job itself is an essential part of it. Work ability describes the balance between the job and human resources. The micro-environment outside work including family, relatives and friends, plays a role in a person's work ability. The societal factors including the legislation, infrastructure, economics, services, incentives, etc. form a larger frame for and background to human work ability. However, the workplace is the environment for work ability because it connects people to their work.

The bottom floor of the house comprises health and functional capacity (physical, mental, and social functioning). The 2nd floor covers the dimensions of competence, and the 3rd floor consists of values, attitudes and motivation. In general, knowledge about health and competences, and how they change with age, are well known. The role of values and attitudes, however, is less known, but experience has shown that the importance of this floor grows when, for example, an effort is made to raise employment rate of older workers. In the 3rd floor individual evaluates the changes in own health and competence as well as in work and in supervision. A negative flow of information and experiences, e.g. from health and work, leads to a deterioration in work ability and a positive flow supports it.

The 4th floor is the largest and heaviest floor of the house. The managers, supervisors and foremen have the power to organize and run the activities on this floor. Increasing job demands, time pressure and continuous changes in the work organization easily create an imbalance between the 4th floor and the other floors.

Recently, a representative population study has been carried out in Finland (Aromaa and Koskinen 2004) including work ability index and a set of variables from each floor of the work ability house. The results show which factors on each floor were significantly related to the Work Ability Index. These results emphasize the role of the 1st and 4th floors - functional capacities and health as well as work life characteristics - suggesting that work life should be better adjusted to the health and functional capacities of older workers (Ilmarinen et al. 2005, Gould et al. 2006). Therefore, basic functions, such as cognitive functions, play an important role in the construction of sustainable work ability during the life course.

3 REVIEW OF LITERATURE ON COGNITIVE AGEING AND WORK ABILITY

3.1 Introduction

The aim of this literature review on cognitive ageing and its relations to age-related changes in work ability is to describe and discuss the research findings since 1980's which are based on representative samples and which are relevant to the work life. We will, however, present also research results based only on age-related cognitive changes although they are not explicitly related to work ability. The review will discuss only research findings based on the so called normal working people samples thus leaving out research of persons who are in the rehabilitation processes. This research field is based mainly on rehabilitation of very different kinds of subjects having limitations in their work ability. We know that this research field is of great importance for understanding the work ability, especially for knowing by which means and how much and how well different rehabilitative treatments can restore already weakened work ability. In this context we have left these research findings out in an attempt to cover the research literature of "normal" subjects in work life. This limitation excludes also those, who for different reasons do not participate in salaried work, as well as those who are nearly always un- or underemployed. These last mentioned cohorts are, however, an important reserve for the predicted work force shortage in the European Union.

In this review we will not discuss genetic factors nor diseases and traumas as factors causing decrements within the cognitive domain. However, it should be remembered that work and the work environment are very significant risk factors for diseases and traumas if working conditions are not monitored through legislation and other work safety rules and regulations concerning the content of work and the work environment.

The age range which is discussed in this article will vary between 45/50–70/75 years. The latter exceeds the most common prevailing retirement ages in western industrialized countries, but there are entrepreneurs in many fields, usually in professions requiring long education, who continue working even after the age of 75/80 years.

This review is based on research findings selected by the criteria mentioned above as well as selected from the relevant bibliographical and data-based sources. The attempt in many countries is to lengthen the working career, as in Finland which has extended the retirement age to 68 years. This is one approach to increase the number of people in work force. The challenge, when extending the work life is to keep work ability as good as possible or at least to slow the decline in work ability. There are many possible approaches to accomplish this including changing the content of work, changing the work environment, and changing the work climate to enhance workers' cognitive processes and work ability.

This literature review begins with describing cognitive ageing approaches primarily from an information processing paradigm. The review includes coverage of age-related changes in sensory channels, attention and sensorimotor reactions, memory system, and intelligence. Age-related changes in wisdom, expertise, and creativity will then be discussed. We find that a discussion of both wisdom and expertise are important and interesting topics since these traits are expected to increase with age while most other information processing abilities decrease. These are some of the few changes that occur in the opposite direction than the majority of information processing capabilities.

Chapter 4 "Cognitive ageing in relation to work ability" reviews the research results concerning both study fields. In addition, it includes also both strong and weak hypotheses of why those cognitive changes are important to work ability. This chapter presents both different factors threatening work ability as well as resource factors to keep work ability intact or weakening as little as possible. At the end of the Chapter 4, age-related changes in work ability will be discussed.

3.2 Cognitive ageing

Human development can, for analytical purposes, be divided into three domains: biosocial, cognitive, and psychosocial. The different domains, or areas of development, interact and thus affect each other during the entire life course. Each aspect of development is related to the other domains and every aspect of human behaviour reflects all three domains. Together these domains also affect the work process an individual is engaged in, but in differing amounts depending on the requirements and content of the job. The human worker is always seen as working as a whole person. While respecting the truth of this, our aim in this article is to first study cognitive ageing in particular and later its relations to a person's work ability. The work ability is a relative concept, which is always related to the requirements and content of the work being done (Tuomi et al., 1998).

The cognitive domain comprises all the psychological processes that are used to obtain and process information to make a decision, and based on this decision making, a possible behavioural outcome takes place. This means that cognitive processes include perception via different channels; it´s processing in different memory systems from sensory-register to long-term memory, language comprehension and production, thinking and learning processes as well as planning, decision-making, and judgement. These represent different levels of cognitive processes. The basic cognitive processes are perception, psychomotor, attention, perception of time and place, linguistic activities, executive functions, memory and learning. The more complex and broader cognitive processes are based on these basic cognitive processes. Examples are thinking, planning, reasoning, problem solving and decision making. Perhaps the broadest and most abstract category of cognitive functioning is intelligence, which comprises various combinations of the different cognitive functions needed for solving the tasks featured in adults' intelligence tests. Also belonging to cognitive functioning are metacognition, knowledge, and ratings concerning self perception, memory, learning and thinking. These are, however, at the same time also connected to the other domains, especially to the psychosocial domain.

Cognitive ageing is affected by many different groups of factors. There are genetic factors (Ly et al., 2000), illnesses and traumas (e.g. Zelinski et al., 1998) as well as the many drugs used in curing different diseases (Mintzer & Burns, 2000), cohort effects (Schaie, 1996, 2000; Schaie & Caskie, 2005), stressors (Cox, Griffiths, & Rial-Gonzalez, 2000, Quillian-Wolever & Wolever, 2002) and, inter-incividually differing ageing processes. All these causes may co-exist and constantly interact with each other.

Organizational demands and relations, job task demands, social relationships at work, the work schedule, work content features, discretionary control and participation, and physical working conditions have been shown to influence the level of job stress. At the same time job stress factors also affect different cognitive processes (Cox, Griffiths, & Rial-Gonzalez, 2000; Kalimo, Lindström, & Smith, 1997). In the stress reaction chain, physical, social, and organizational stressors affect, via individual resources or lack of them e.g. high level of cognitive functioning, knowledge, and expertise, the coping processes of the individual worker. The worker may use either problem-based or emotion-focused coping-processes or a mixture of both to handle stressors. If workers have a high level of cognitive resources, it is more probable that they will use problem-based strategies to either reduce the impact or else resolve the issues caused by stressors. The short-term adverse consequences of these stressors may be physiological, psychological, or behavioral. Stressors can also manifest themselves in the weakening of different cognitive processes such as attention, the inability to concentrate, memory problems, and generally in planning and thought processes. If the effect of the stressors continues for a long period, longer lasting health and cognitive outcomes will be seen e.g. diseases, disabilities, early retirement as well as premature deaths.

It has been shown that the multiple aspects of attention, concentration, information-processing speed, short-term memory, awareness, insight, decision making, and judgment all change in response to stress (Kalimo, Lindström & Smith, 1997; Quillian-Wolever & Wolever, 2002). The above groups of factors that are affected by stress, impact on the ability of an individual to work. The reason why stress impacts on an individual's ability to work is because in every task cognitive functions are necessary, although to varying degrees depending on the job task and the type of functions required by the worker for successful task performance. Both cognitive and stress factors also affect the necessary physical activities of daily living (PADL) and instrumental activities of daily living (IADL). However, not all stress factors need necessarily weaken cognitive functioning. On the contrary, some of them can be prevented or their effects slowed.

Ritchie and Lovestone (2002) have presented a list of risk factors which are preventable that can adversely impact cognitive functioning. These risk factors include head traumas, increased blood pressure and cardiovascular diseases, depression, reduction of cholinergic burden, improving cholinergic functioning, use of anti-inflammatory agents, and being in a non-stimulating environment. It is well-known that preventive measures are very often based on the content of work, the work environment, and the work climate. Also, it is possible among the younger generations to improve on the cohort related factors known to be associated with cognitive functioning, such as health-care, nutrition, education, work content and work environment.

Salthouse (1991) has summarized the earlier research on age-related changes in the cognitive domain, focusing on the greatest and smallest age-related changes in cognitive functioning. The smallest age-associated changes have been found for tasks which are based on previously learned, familiar, well-stored information representing the accumulation of experience and in which time restrictions are not great. Among the different intellectual functions, involved in the work task, verbal comprehension and vocabulary have repeatedly been shown to be the most stable (Schaie 1996, 2005).

Horn and Cattell (1967) have named stable cognitive functions "crystallized intelligence". Many years ago Horn and Cattell (1967) drew a distinction between fluid intelligence, meaning abstract thinking, reasoning, rapid problem-solving and decision making, and crystallized intelligence, which includes a person's information storage, linguistic skills, general knowledge and vocational and professional skills. These two kinds of intelligence are in constant interaction. Fluid intelligence achieves its top level at the age of 25 to 30 years, and crystallized intelligence at the age of 65. The weakening of fluid intelligence is quite rapid; the decrease in crystallized intelligence becomes more abrupt after the age of 75-80 years.

The largest age-related changes in cognitive functioning have been found in tasks which require the learning of new information, especially nonverbal information, which is unfamiliar and unpractised, and in which adaptability and rapid adjustment are needed. Tasks necessitating quick and accurate reactions, and generally requiring speed, flexible handling of data and mental agility are also generally much easier for younger than for older people. It has also been stated that new tasks which require understanding of new methods or a new kind of thinking, e.g. the thinking necessary for adopting new methods of working, are more slowly learned among older than younger people. Horn and Cattell (1967) have named these rapidly deteriorating intellectual functions "fluid intelligence", with abstract reasoning in handling new material in which rapid responses are necessary.

Chastain and Joe (1987) reported on a factor analytical study which examined multidimensional relations between intellectual abilities and demographic variables. They noted that education, race, and occupation loaded on a general factor which they described as crystallized intelligence.

The second factor which they named "fluid intelligence", loaded on the performance scales, age, and single marital status. Thus, in this study, age was more strongly and clearly associated with "fluid" than with "crystallized intelligence". Moreover, "fluid intelligence" declined with age more rapidly than did "crystallized intelligence".

Since the summary by Salthouse (1991), many new research results, describing age-associated decrements in the cognitive domain, have been published. These studies tend to be more analytical in their approach to the different components of information processing than their predecessors. Because of this difference, we feel compelled to scrutinize the later studies more thoroughly to be able to discriminate the decrements which are essential to work ability.

The possibility that cognitive functioning can improve has been the subject of speculation, but this interest has not yet been translated into a body of directly relevant empirical evidence (see, however, Ruoppila & Suutama, 1997a, 2003; Schaie, 2005). Very little is presently known about how adult cognition may improve with age and this phenomenon of cognitive growth, may be restricted to select cognitive processes in a few individuals (Smith & Baltes, 1990). This lack of knowledge about age-related improvements in cognitive functioning may be a consequence of the difficulty of investigating such complex cognitive processes, such as wisdom, which is frequently mentioned as achieving its highest level in late age (Baltes & Smith, 1990: Baltes & Staudinger, 2000; Baltes, Staudinger, Maercker & Smith, 1995; Birren & Fisher, 1990; Smith & Baltes, 1990; Smith, Staudinger & Baltes, 1994; Staudinger, 1999; Sternberg, 1990, 1998; Sternberg & Lubart, 2001).

Also, based on what has been presented above, we would expect both work and the work environment to impact, and be impacted by, cognitive functioning with the effects measurable well into retirement. Such effects, however, can only be measured through use of longitudinal research designs, which allow for frequent measures of cognitive functioning in both the work and in the post retirement environment. Studies of this kind have been lacking until now.

Cognitive development in adulthood is also affected by formal education and by life-experiences in which work plays a very important role, resulting, in some cases, in the acquisition of expertise and wisdom. Because of the very broad categories of these functions which belong to the cognitive domain it is necessary to confine ourselves to those which are the most important from the work-process point of view.

Cognitive ageing has been widely studied but mainly through use of the cross-sectional design. Cross-sectional designs, which measure age differences between cohorts, provide a very different description of cognitive ageing than longitudinal studies, which measure age changes within a cohort. Moreover, cross-sectional designs have long been shown to be cohort confounded that is the differences between cohorts could be the result of differing environments, differences in education, differences in diet, or any number of other factors that could have differentially affected one age group over another resulting in the observed differences in cognitive ageing. Longitudinal studies are confounded by effects of history, practice effects, instrumentation, statistical regression, experimental mortality, selection, and the selection-ageing interaction (Schaie & Hofer, 2001). The confounds (ACP: age, cohort, period) resulting from these approaches provide methodological research problem that are very difficult to solve in empirical ageing research (Schaie, 1965, 1986, 2000). Because of the difficulties in comparing studies that have used these various approaches, we have limited our analysis to research work utilizing longitudinal designs, which focused on age changes, that have been published since 1980.

Fortunately, there has been an increase in the number of longitudinal studies, making it at least partly possible to describe and analyse intra-individual cognitive changes during ageing, and also to begin to understand adult cognitive development. However, also even in longitudinal studies, there are confounders regarding cognitive ageing. These involve the effects of history, testing, instrumentation, statistical regression, experimental mortality (attrition) and selection. The consequences of these validity threats have been discussed, e.g. by Schaie (1988) and Schaie and Hofer (2001). An important limitation of most longitudinal studies on cognitive ageing is that the samples used are relatively strongly selected ones. Their findings are not representative as regards the whole population. Almost no studies have used community samples representing the whole ageing population (see, however Laursen, 1997; Ruoppila & Suutama, 1997a, 2003).

Also, it has to be emphasized that the great majority of longitudinal studies in the field of cognitive ageing have been concerned with the phenomena of cognitive decline. As a consequence, the negative relations between age and cognition are well-established, but with little consensus on how they are to be explained (Schaie, 2000).

3.3 Information processing paradigm and cognitive ageing

3.3.1 Changes in sensory channels

The information process begins with the different senses that receive and select information. These sensory channels - vision, hearing, taste, touch, and smell - are vulnerable to age-related change. With age, greater intensity of stimulation is generally required to make the same impact on the sensory system that was once achieved with lower levels of stimulation. Some age related declines begin in early adulthood, and their effects increase throughout the remainder of the life course (Schaie, 1996, 2005). The most important vision changes with respect to work life are sharp declines in visual acuity after age 40, delayed adjustment to shifts in luminosity and increased sensitivity to glare, and increased problems in performing daily visual tasks after age 65. These changes are partly caused by diseases of the eye that produce partial or total blindness, although this is rare (Fozard & Gordon-Salant, 2001). In hearing there is a continued gradual loss in pitch discrimination from the age of 50 and a sharp loss in pitch discrimination after 70: sound must be more intense to be heard (Fozard & Gordon-Salant, 2001). Age-related changes in the other sense modalities have been studied much less than those in vision and hearing. However, it is known that with regard to taste and smell, the loss of taste buds begins in the 40s. At 65, higher thresholds are required for detecting tastes and smells (Miller, 1988; Spitzer, 1988), and errors in identifying odors increase (Stevens & Cain, 1987). Age-related changes in other sense organs will not be discussed because of the scarcity of data on age related declines. Moreover, these senses (e.g. kinesthetic, bodily orientation, various skin senses) are only important in a few jobs.

Fozard and Gordon-Salant (2001, p. 241) conclude that "Convergence of laboratory findings with findings from population-based studies and longitudinal studies indicate that senescent changes in certain auditory and visual functions are only observed in the oldest age decades (over 75 or 80 years)". However, vision is important for the successful performance of many complex tasks such as maintaining balance. It has been found that sway increases with age equally in men and women and that this is always worse when the eyes are closed, when conditions resemble darkness. The age-related increase in sway is attributed to a slowing of the integration of the central nervous system in information processing. There are studies on vision in relation to age differences in speed of walking, gait, stumbles, and falls, all of which are important from the work safety and general safety point of view (Fozard, 2000: Fozard & Heikkinen, 1998).

Perhaps the most intensively studied complex problem has been the relation between vision and driving. Owsley and colleagues (Owsley, McGwin, & Ball, 1998) reported that of the many visual functions evaluated, restrictions in the useful field of view and glaucoma were significant risk factors for accidents. There are also studies showing that healthy older drivers drive slower, brake less often, make fewer steering and eye movement excursions, and drift across the centre line more frequently than young drivers (Perryman & Fitten, 1996). Steering errors also increase with age, and especially under conditions of poor illumination (Owens & Tyrrell, 1999). For the elderly people high levels of illumination are also important for reading and other visual tasks. In practice increasing illumination is, perhaps the easiest and most feasible way to correct working and home environments.

Hearing can also be analysed through many different measures. Hearing problems are the most frequent type of impairment reported by elderly individuals, especially after 65 years of age. One hearing impairment attributed to age, presbycusis, is very difficult to discriminate from other factors causing hearing loss, like exposure to noise in work. The ability to follow a conversation among people who are talking to each other is the most sensitive measure of ageing effects (Era, 1987; Laukkanen, Leinonen & Heikkinen, 1999). Understanding a conversation is already difficult between two elderly persons. Generally, age-associated deficits emerge in speech recognition tasks, but the effects are highly dependent on the type and extent of speech impairment, and on the demands of the listening task.

Gender differences show elderly women to have better hearing than elderly men. This is based on the fact that during their earlier work career as well as in other environments, e.g. in war, men have been exposed more often to noise which is known to impair hearing and other cognitive functions.

Age-related deficits in hearing have been observed in most studies and in most measures used; however, the extent of ageing effects is largely influenced by the complexity of the stimuli and task. Increasing hearing difficulties are much more important for work ability than the weakening of visual functions because, in practice, listening and comprehending what is said is of the utmost importance in nearly all kinds of work. Moreover people are willing to use glasses to compensate for visual losses, but not, at least until now, to use a hearing aid to compensate for hearing losses. Hopefully, in future cohorts hearing losses will be milder and begin later than in the present cohorts because the noise level in working environments in many instances has been lowered greatly, but not necessarily in other environments.

The problem of noise is that it not only affects hearing but also other phases in the information processing chain such as attention, memory, thinking and learning as well as causing stress, which accentuates the abovementioned effects. Noise is the most important occupational cause of hearing loss, but solvents, metals, asphyxiants, and heat may also play a role. Exposure to noise, usually combined with other agents, can result in hearing losses greater than those resulting from exposure to noise or other agents alone. Noise can also produce transitional increases in blood pressure which may lead to cardio-vascular diseases. This may be due to psychological factors related to stress reactions, which in turn impair different cognitive functions (Smith et al., 2002).

The findings by Baltes and Lindenberger (1997) are of great importance: they demonstrated a strong correlation between visual acuity, auditory pure tone thresholds and several measures of intellectual functioning. These correlations were higher in the oldest adults, but significant also in younger groups. The increasing correlations were interpreted as reflecting a common pattern of brain ageing that affected both types of measures. An alternative hypothesis, that sensory deprivation in older age results in poorer performance, received less support. The theoretical explanation by Baltes and Lindenberger (1997) has, however, been challenged, e.g. by Anstey et al. (2003). So it is not yet fully established how these decrements in sense organs and neural functions interact to produce the known age-related losses in vision and hearing, and how these are related to age-related changes in the cognitive domain. These decrements do not necessarily change at the same time, nor are the factors behind them the same.

Anstey and Smith (1999) have also examined interrelationships among biological markers of ageing, health, activity, acculturation, and cognitive performance in late adulthood. The biological markers (BioAge; vision, hearing, vibration sense, forced expiratory volume, and grip strength) of ageing explained all the age-related variance in cognitive test performances in their sample of women. Also, physical health and physical activity had direct effects on BioAge. Measures of acculturation explained non age-related variance in cognitive functioning. Some biomarkers also explained individual differences in measures of crystallized intelligence and perceptual speed. The authors concluded that the association between biomarkers and cognition is due to more than a common statistical association with age.

In summary, recent data indicate that both vision and hearing are adversely impacted by the behavioural slowing and cognitive decline that occur with increasing age. There is a complex pattern of age differences in neural function that is experimentally distinguishable from age differences in end organ function (Fozard & Gordon-Salant, 2001). Although these impairments are not completely unavoidable, there is an increasingly wide range of possibilities available for improving or compensating for sensory and perceptual impairments of older persons, whether in the form of environmental interventions (Fozard & Gordon-Salant, 2001) or by personal technological aids.

3.3.2 Changes in attention and sensorimotor reactions

The information gathered from the sense organs will be selected by the attention process. Parasuraman (1998) has suggested that there are three primary components of attention: selection or direction of attention, vigilance, and control of attention. The latter refers to an individual's ability to direct, change and select his/her attention. These functions are critical for enabling individuals to perform different functions. Alain and Woods (1999) found that the age-related changes in processing task-irrelevant auditory stimuli were consistent with the inhibitory deficit hypothesis and suggested that impaired inhibitory control of sensory input may play a role in the age-related decline in performance during selective attention tasks. Also, Falkenstein, Hoormann and Hohnsbein (2002) found in their cross sectional study, that the elderly's ERP (event related potential) results revealed a slight impairment of modality specific inhibition after visual, but not after auditory, stimuli. General inhibition was delayed in the elderly for both modalities. The authors concluded that the slowing of response in the elderly is the result of a slowing of the decision process, i.e. whether to respond or to inhibit. Both aspects of inhibition were related to age in a different manner.

Rogers and Fisk (2001) in their review state that the relations between age and different aspects of attention remain unclear or unsure. There are only hints that during ageing the inhibition of unessential information weakens and that this impairs selective attention, especially in complex tasks. It is possible to conclude that different aspects of attention are weaker among the elderly than with young people in complex situations demanding data storage in the short-term memory and which at the same time include significant disturbance factors (like noise). Also, the deterioration in vision and hearing are connected with problems in tasks which set high demands on attention, like working conditions in which new information technology is much used.

It is well-known that during ageing structural and functional changes accumulate over time and contribute to decrements and abnormalities in movement control (Brown, 1996). There are several sensorimotor changes that occur with increased age, including neuroanatomical reductions, muscular changes, reduced proprioception and decrements in sensorimotor integration (Ketcham & Stelmach, 2001). Sensorimotor actions are for the most part automatized and are most often subconscious, as in maintaining balance, controlling movements and using muscles. As regards information processing, the most important change is in reaction time, which to date has also been the most studied sensorimotor reaction. The findings clearly show a slowing both in reaction time (time from the onset of the stimulus to the beginning of the motor reaction) and in movement time (time needed to perform the necessary task). Madden (2001) concludes that this slowing begins in early adulthood. It is not necessarily a linear change as decrements can occur unevenly at different ages.

The general explanation for the slowing of reaction time is that it may represent a generalized, systematic age-related slowing of cognitive performance, which holds across a variety of tasks, rather than changes in specific information-processing components (Cerella, 1985; Salthouse, 1985, 1988, 1998). The general slowing-down hypothesis, presented first by Birren (1965; but see also Jalavisto, Lindqvist & Makkonen, 1964), has received near universal acceptance. This implies that a substantial proportion of age-related variance in the speed and timing of performance is shared across a wide range of cognitive tasks, while at the same time some age-related slowing takes place which is specific to particular task demands.

Sliwinsky and Buschke (1999) have examined cross sectional and longitudinal relationships between age, cognition, and processing speed. They noted that processing speed was related to cross-sectional cognitive performance, and that changes in processing speed predicted within person longitudinal cognitive decline. Statistical control for processing speed greatly reduced the cross-sectional age effects but did not attenuate the longitudinal ageing effects. Similarly, Hertzog et al. (2003) in their 6 year longitudinal study found that their latent change models revealed reliable individual differences in cognitive change. Changes in episodic memory were significantly related to changes in other cognitive variables, including speed and working memory. Changes in speed and working memory predicted changes in episodic memory, as expected by the processing resource theory. These effects were best modelled as being mediated by changes in induction and fact retrieval.

Salthouse (1994) analyzed the relations between age, motor speed, perceptual speed, and three measures of cognitive performance (study time, decision time, and decision accuracy). He concluded that increased age was associated with lower accuracy as well as with longer study time and decision time, and that some of the relations between age and decision accuracy and between age and decision time appeared to be mediated by a slower rate of executing cognitive operations.

It is likely that both generalized and task-specific effects can be discerned in the results of any investigation of age-related slowing (Lindenberger & Reischies, 1999; Schaie & Caskie, 2005). The more complex the task to be performed or the more complex the situation in which it is to be performed, the greater the extent of slowing with age. However, this global single factor speed theory as well as many other similar ones have been criticized recently by Rabbitt et al. (2003). They point out that overly strong generalizations have been made on the basis of studies and experiments which used limited and small samples. Accordingly all the age-related changes observed in perceptual speed, sensorimotor functions, and intelligence tests can not be explained by a single speed factor; instead there are probably a variety of different speed, task and context specific factors behind these changes, and qualitative changes as well as quantitative ones (Rabbitt et al., 2003).

Rabbitt et al. (2003, p. 567) emphasize that there is no evidence that age reduces, instead it is changes that occur with age, which reduces the speed of the fastest responses that people make. Older cohorts' mean and median choice reaction times are slower, not because members of the cohort cannot make fast correct responses but because they choose to make slower responses. This finding is analogous to findings that fatigue and stress do not increase mean or median choice reaction times but do markedly increase the numbers of correct responses that are more than 1.5 SD slower than the distribution mean or median. One explanation for these exceptionally slow responses is that they represent lapses of continuous attention which cause "blocks" or "gaps" during which information processing is slowed or interrupted (Rabbitt et al., 2003, p. 568).

3.3.3 Changes in memory system

The information which has been selected in the attention phase of the information processing sequence enters the memory system. Memory can be conceptualized as being generally divided into episodic and nonepisodic forms. In relation to information-processing the memory is usually divided into a sensory, short-term memory, including primary and working memory, and a long-term memory. As Bäckman, Small and Wahlin (2001) and Henry et al. (2004) have concluded, no single variety of human memory is completely immune to the negative influence of ageing on performance. However, there are large differences in how great age-related deficits in the different forms of the memory are. Evidence suggests that age-related deficits in primary memory (i.e., holding information in the consciousness) are very small (LaVoie & Light, 1994). Also in priming, which refers to the unconscious facilitation of performance following prior exposure to a target item or related stimulus (Schacter, 1987), age-related differences are small or practically nonexistent. In the procedural memory, which underlies the acquisition of skills and other aspects of knowledge that are not directly accessible to the consciousness and the presence of which can only be demonstrated indirectly by action (e.g. cycling, automatized movements needed in work-processes), and the semantic memory on the other hand, which deals with the general knowledge of the world, including meanings about words, concepts and symbols, their associations and rules for manipulating these concepts and symbols (Tulving, 1983), age-related deficits may or may not be observed depending on the specific task demands.

Tasks assessing working and episodic memory typically exhibit a marked deterioration in performance from early to late adulthood (Light, 2000). For learning, the capacity of the working memory is very important. Salthouse and Babcock (1991) have found that deficits in the processing component of the working memory constitute the major source of the deterioration in performance. These also depend on the strategies older persons use to cope with the conflicting demands of a working memory task (Brébion, Smith, & Ehrlich, 1997).

The episodic memory, especially as regards the time and place of earlier episodes, is the most vulnerable to age-related decline (Nilsson et al,. 1997; Salthouse, 1998). A very important observation from the work ability point of view is that older persons generally have more difficulties than younger ones especially in the growing amount of new information one should store in the memory. However, it is possible at least partly to compensate for memory loss with enhanced retrieval support. An important finding is that the age-related variance in memory performance may be shared both with that in other cognitive domains and that in non-cognitive domains (e.g. sensory and motor functioning) (Anstey, 1999; Baltes & Lindenberger, 1997; Salthouse, 1998).

The working memory captures both the storage functions of the short-term-memory, and the processing and controlling functions of the working memory under a uniform theory of the on-line memory. The working memory comprises three principal components: the central executive, the phonological loop (Baddeley, Gathercole & Papagno, 1998), and the visuo-spatial sketchpad (Baddeley, 1986). The working memory framework has recently been revised by Baddeley (2000). The revised model focuses attention on the processes of integrating information, rather than on the fractionation of the subsystems. It also introduced a new component, the episodic buffer, which has been put forward to deal with abstract representations of events.

The central executive is considered to be the most important component of the working memory in terms of its general impact on cognition. It most closely conceptualises the resource for coordination in working memory (Baddeley, 1986; Schneider & Detweiler, 1987). The central executive is presumed to control and supervise working memory functions and the flow of information between components of the working memory rather than to represent the memory store. It is involved in the execution of flexible strategies for the storage and retrieval of information, in the retrieval of knowledge from the long-term memory, in the control of action planning, and in the scheduling of concurrent cognitive activities (Baddeley, 1996).

The question whether the central executive comprises different fractionable cognitive functions, or is a uniform system, remains open. Baddeley (1996) concluded that there are at least four different cognitive processes carried out by the central executive which can be regarded as representing separate functions. These are: 1) the capacity to co-ordinate the performance of two separate tasks; 2) the capacity to switch between retrieval strategies; 3) the capacity to attend one stimulus and to inhibit others; and 4) the capacity to hold and manipulate information in the long-term memory. In question is whether the resources available to the central executive are domain-specific or not (e.g. Shah & Miyake, 1996; Swanson, 1999). However, the central executive is generally assumed to be needed in both verbal and visual tasks which include the simultaneous storage and processing of information.

Wecker et al. (2000) studied age effects on executive ability. They found that age had a significant effect on the requirement of executive functioning, where speed, particularly, decreased. Age did not affect switching performance but age was associated with the commission of certain types of errors. The authors emphasized specificity over generalizability in relation to the impact of age on cognition. Also Lamar, Zonderman and Resnick (2002) on the basis of their study stress the importance of considering executive and non-executive aspects of cognition when conceptualizing executive functioning.

Verhaeghen and Salthouse (1997) conducted a meta-analysis, based on 91 studies, to derive a correlation matrix for adult age, speed of processing, primary-working memory, episodic memory, reasoning, and spatial ability. Their general finding was that all cognitive measures shared substantial portions of age-related variance. The speed of processing and primary-working memory appeared to be important mediators of age-related differences in the other measures. In addition they observed that age-related decline accelerated significantly over the adult life course for variables assessing speed, reasoning, and episodic memory.

Jenkins et al. (2000) found in their series of three experiments that older adults were generally slower than younger adults in all speed tasks, but that age-related slowing was much more pronounced in visuo-spatial tasks than in verbal tasks. Older adults showed smaller memory spans for letters than young adults, but memory for locations showed a greater age difference than memory for letters. Finally, older adults had greater difficulty learning novel information than young adults, and greater deficits learning visuo-spatial than verbal information. The authors concluded that the differential deficits observed on both timed and untimed tasks strongly suggest that visuo-spatial cognition is generally more affected by ageing than verbal cognition.

In their recent review Rabbitt et al. (2003, p. 565) state " there is growing evidence that tasks that are disproportionately slowed by age tend to be those that involve functions attributed to the central executive system, and supported by the frontal and prefrontal cortex". This line of research is based on an increasing number of studies which have been interpreted to show that "normal" or "usual" ageing produces structural changes earlier and more rapidly in the frontal lobes than in other parts of the cortex even in the absence of pathology. These changes include shrinkage of neurons, loss of dendritic masses, reduced cerebral blood flow to the anterior cortex, decline in levels of neurotransmitters such as dopamine, region-specific declines in concentration, synthesis and number of receptor sites for some neurotransmitters, and a loss of myelin (Rabbitt et al. 2003, p. 565). If, as Hasher and Zacks (1988) assumed, inhibition functions less efficiently in older adults, their selection of information will be incomplete so that irrelevant information will gain access to the working memory, information that is no longer relevant will continue to remain active in the working memory and attention will frequently be given to inappropriate information.

Rabbitt et al. (2003, p. 579) concluded that global single factor theories of cognitive change with age confuse levels of description; that these theories rest on the assumption that old age slows performance on all tasks by the same amount. This is not in fact the case, as there is accumulating evidence that tasks involving "central executive" processes, and mediated by the frontal or prefrontal cortex, show greater age-related slowing than others and also occur earlier, and are more substantially affected by ageing, than other tasks; that there are age related increases, in the numbers of unnecessarily slow responses, that individuals make; and that global single factor speed theories of ageing do not account for age-related changes in memory.

When elderly persons complain that they have memory difficulties it is usually a question of metamemory or more generally metacognition, that is, how people rate their information processing capacity. The correlations between memory test performance and self-ratings of memory are positive, but generally low. However, these negative self-evaluations can become self fulfilling prophecies which can tend to increase objective memory-deficits. The positive thing is that elderly persons can compensate for these memory problems by using different memory-aids.

A weakening memory as well as the slowing down of information-processing affects learning. Moreover, attention is an important factor for learning. Learning in old age has, however, been studied much less than memory processes. Tasks which require the prolonged maintenance of attention and the ability to keep many different factors in mind at the same time are more difficult for elderly than younger persons. The strategies a person uses for acquiring new information are very important for learning. Generally, the most effective strategy is deep-processing i.e. trying to understand and comprehend the material which is needed to learn. Its opposite is surface processing meaning mechanical and superficial learning. There are some important characteristics which support learning in advanced age. These are a calm and peaceful atmosphere, links with the earlier experiences of the learners, effective repetition and teaching the use of effective learning strategies for the task at hand. Elderly persons are also more cautious and can become anxious more easily in new learning situations, which is why they need more support, especially in the early stages, to overcome these feelings. When elderly people decide to acquire new information this means that they are also highly motivated, which supports the learning task.

3.3.4 Changes in intelligence

Baltes (1993), on the basis of the strength of age-related changes in intelligence functions, has also managed to differentiate fluid mechanics and crystallized pragmatics. Baltes views fluid mechanics, metaphorically, as information-processing mechanisms of the mind, and pragmatics as the programs of the mind. These, again, are in constant interaction with each other.

Schaie's (1996, 2005) study was based on factorial intelligence tests. The study began in 1956 and a new cohort was added every seventh year, the last in 2005. The age-range has varied between 22-96 years. The most important findings were that the age related declines in intelligence are not uniform in their onset; and that the extent of the individual declines differs with regards to slope and direction of change. Recently, Schaie 2005 has concluded that the weakening of different abilities starts with perceptual speed between 30 and 40 years, with some abilities not weakening until age 60, and other abilities showing onset of decrements 5 to 10 years later. Perhaps of greatest import was that verbal comprehension was not found to weaken until approximately at age 80 years. Schaie and colleagues have noted that gender differences have always been very small in their project to the point that, for all practical purposes they were considered insignificant. It should be noted that there were a minority of participants whose test results improved during ageing. These findings have great relevance as regards work ability because the decrease in work ability has been shown to begin at approximately age 45 and continues more rapidly thereafter. Of the intellectual abilities only perceptual speed shows a similar age-curve. Possibly, not only reduced perceptual speed but age-related changes in information processing, especially in executive functioning, can also partly, but only partly, be seen in the Work Ability Index age curve (Ilmarinen & Tuomi 2004).

We have to keep in mind that when we are studying age-related processes the selective mortality must be taken into account. As regards cognitive functioning a high age-expectation is related to a high level of cognitive functioning and vice verse (Schaie, 1996, 2005).

One criticism levelled at the use of standardized intelligence tests, when studying age-related changes, is that these may not measure the same domains in an elderly sample as they do in a younger sample. Allaire and Marsiske (1999) examined the relationships between a new battery of everyday cognitive measures, which assessed four cognitive abilities within three familiar real world domains, and traditional standardized psychometric tests of the same basic cognitive abilities. The results indicated that the cognitive tests were strongly correlated with the basic cognitive abilities. Several of these basic abilities, as well as measures of domain-specific knowledge, predicted everyday cognitive performance. Moreover, everyday and basic measures of cognitive functioning were found to be related to age. The authors concluded that everyday cognition is not unrelated to traditional measures of cognition, nor is it less sensitive to age-related changes.

One new construct, emotional intelligence (Goleman, 1995), has now been examined sufficiently to suggest that this construct or series of constructs deserves serious attention. However, there is a need to conduct convergent and divergent validity studies on midlife and older samples and examine emotional intelligence with reference to the intelligence domain during the life course. Once properly validated, the construct can be used to study the emergence, age differences, and age changes in the level and structure of emotional intelligence as well as its associations with the intelligence domain and with work-ability during the life course (Schaie, 2001).

3.4 Age-related changes in wisdom, expertise and creativity

3.4.1 Wisdom

Wisdom and expertise have usually been the only individual characteristics hypothesised to increase with age. Wisdom, however, has only been experimentally studied for a short period (Baltes & Smith, 1990; Staudinger & Werner, 2003). Baltes and Smith (1990) described wisdom in the context of solving life-management problems according to five different characteristics. They evaluated these characteristics on the basis of written or oral protocols produced by persons solving applied problems. The five components of their model were (a) a rich factual knowledge (general and specific knowledge about the conditions of life and its variations), (b) rich procedural knowledge (general and specific knowledge about strategies of judgment and advice concerning matters of life, (c) life course contextualism (knowledge about the contexts of life and their temporal or developmental relationships), (d) relativism (knowledge about differences in values, goals, and priorities), and (e) uncertainty (knowledge about the relative indeterminacy and unpredictability of life and ways of coping). A wise solution should reflect the use of these components.

Different empirical evidence (Baltes, Smith, & Staudinger, 1992; Baltes & Staudinger, 1993, 2000) has shown the utility of the proposed theoretical and measurement approaches to wisdom as well as its relationship to age (Staudinger, 1999). Staudinger has pointed out that older people profit more than younger people from opportunities such as being given time to discuss a life-related problem with a peer, and then being given time to reflect on this discussion. Thus, giving older people a chance to develop 'interactive minds' may be particularly facilitative in indicating their potential for wisdom. Also it has been found that people become wiser at a given age with respect to the kind of problems that confront them at that point in their lives (Staudiger & Baltes, 1996).

In the few empirical studies in which wisdom-test findings have been correlated with different intelligence and creativity tests, the correlations, while low, have been positive and significant, but quite low (Staudinger et al., 1997). Wisdom involves building complex cognitive networks to successfully adapt to and solve life's challenges. Wisdom also requires the integration of multiple types of knowledge and skills concerning practical and ethical issues in human life (Baltes & Staudinger, 1993; Smith, Staudinger & Baltes, 1994; Sternberg, 1990, 1998; Vaillant, 1993). It requires an implicit, complex, effective knowledge network combining multiple domains over time and extensive experience, and it seems to require the special coordination of emotional, social, and cognitive processes. Wisdom seems to compensate for physical slowing in middle and old age, enabling many persons to perform synthetic thinking, often making people competent as political leaders, judges, and scholars. Adults can deeply and broadly develop their skills, building complex identities, creating new ideas, practices, or products that shape their society, and building wise ways that go beyond self-interest and immediate response. These outcomes depend on the development of networks connecting multiple strands in the web of skills and emotions (Fischer, Yan & Stewart, 2003).

3.4.2 Expertise

Expertise and creativity are concepts which are partly related to wisdom, and which have been used in work-contexts more often than wisdom. Expertise is also often seen as a construct which is developed over long and diverse experience gathered during the earlier life course, especially the work career.

Early studies in cognition primarily addressed the basic-information-processing capabilities employed by subjects in problem-solving situations where they lacked specialized knowledge and skill. The information-processing model suggested by Newell and Simon (1972) and the Adaptive Control of Thought (ACT) model developed by Anderson (1983) represented the mainstream approaches which previously predominated in cognitive psychology studies of expertise and the learning of cognitive skills. Newell (1990) believed that people transit smoothly into a problem-solving search, and that much of human cognition is a mixture of routine problem solving and the acquisition of problem solving that involves search. Anderson (1983) attempted via his model to give a process-description of problem solving and cognitive skills. He made a distinction between declarative knowledge, which encodes factual knowledge, and procedural knowledge, which encodes many of the cognitive skills, including problem-solving skills. Another main line in cognitive psychology linked to expertise involves the study of human memory systems. This approach has generated the notion of chunking, which is understood as the basic mechanism for overcoming the limitations of human short-term memory in the learning of cognitive skills.

In studies of semantic memory, the notion of the schema in its different versions has also been a powerful concept in describing the general structures of the knowledge stored in the long-term memory. A schema has been understood as a higher-order knowledge structure representing the generic concepts stored in the memory. A schema is at the same time a network consisting of variables, the value of a variable and knowledge of how to use it. All the pieces of knowledge associated in a certain domain are hierarchically organized, and the whole structure is called the knowledge base (Chan, 1990).

Research on expertise has given rise to the introduction of an additional memory system called the long-term working-memory (LT-WM). This has been considered necessary for the understanding of expert memory functioning and retrieval (Ericsson & Kintsch, 1995). The properties of the memory provide information that is relevant to the interpretation of several aspects of expert performance. The size of the wholes which can be actively manipulated in the working memory increase with increasing skills. Experts are better at constructing large working-memory representations than less experienced novices (Saariluoma, 1995). Ericsson and Kintsch (1995) suggested that the construct of the LT-WM is needed as a domain-specific construct to explain skilled human activities in complex tasks. Saariluoma (1995) concluded that memory systems offer several functions that are important in the selective thinking of experts, but the vitally important aspect of selectivity seems to go beyond current memory research. There is no adequate explanation of the selection of content-specific information and thus of the content-specific aspects of selective thinking. The problem with current concepts of the expert memory is that these concepts do not have content-specific attributes.

Over the last few decades there has been an increase in research on how the transition is made from novel to routine problem solving as a person gathers experience within a problem domain. This reflects a shift in interest both towards learning and towards knowledge-rich real problem-solving domains, as the task demands used in studies carried out in experimental settings have often been at an elementary level, far removed from the demands of real complex professional tasks.

From the 1980s onwards, expertise research has increasingly focused on knowledge-rich tasks requiring thousands of hours of learning and experience. Studies in semantically rich domains (e.g. physics, algebra, medical diagnosis, and programming) have offered insights into the learning and thinking of experts, who require a rich structure of domain-specific knowledge.

It has been generally confirmed in several studies of cognitive skill acquisition that experts are usually faster than novices in their domain problem-solving, and that they also make fewer errors than novices. The main qualitative differences found in expert-novice comparisons can be summarized as follows (Ericsson & Lehman, 1996; Eteläpelto, 1998; Gruber, 1994; Holyoak, 1991; Saariluoma, 1995; Sonnentag, 1995):

(1) experts perceive large meaningful patterns in their own domain
(2) experts focus on the relevant cues in the task
(3) experts represent their domain problems at a deeper level than novices
(4) expert knowledge is organized in a way that is relevant for problem solving
(5) experts use more time in problem analysing and constructing a detailed mental representation of the problem before they enter into the solution
(6) experts' knowledge structures are hierarchically organized and have more depth in their conceptual levels than those of novices
(7) experts categorize problems in their own domains according to abstract high-level principles and their knowledge structures are more coherent than those of novices
(8) experts have better self-monitoring skills than novices
(9) high-performing professionals spend more time on problem evaluation.

A knowledge-based approach to expertise research is fruitful and capable of contributing to a more realistic understanding of the nature of expertise and its learning conditions. In a recent summary, Feltowitch, Ford, and Hoffman (1997) took the view that many new findings have been established and that many aspects of the cognition of expertise can now be characterized fairly well. However, there are also limitations in the knowledge-based approach which have been criticized To summarize the main criticism (e.g. Eraut, 1994; Gruber, 1994; Rambow & Bromme, 1995) expert-novice comparisons have operationalized expertise mainly in terms of the length of experience. The comparisons tend to overestimate the role of practice as the main source of expertise. This is why some employees, despite having worked at a task for many years, are still not very skilful. Cross-sectional expert-novice comparisons have also been criticized for giving a static and uniform picture of professional expertise (Eraut, 1994; Gruber, 1994).

Studies addressing open and ill-defined tasks have shown that there is a great deal of qualitative variety in the nature of individual subjects' solutions, and that such variety can reveal a great deal about the nature and quality of learning which produced the expertise. The nature and variety of subjects' experience explains their high expert performance more accurately than the length of their work experience (Sonnentag, 1995; Waltz, Elam & Curtis, 1993). Given that the length of experience within a domain is generally a weak predictor of performance, recent research has tried to identify the most effective training activities for improving performance within the domain (Ericsson, Krampe & Tesch-Römer, 1993). To attain exceptional levels of performance, people must undergo a very long period of active learning during which they refine and improve their skills, ideally under the supervision of a teacher or coach. Nobody achieves a high level of performance in any domain without a great investment of time. Biographical studies have confirmed that in a number of domains, the minimum period of practice needed to attain excellence seems to be about ten years of intense preparation (Ericsson & Charness, 1994; Ericsson & Lehman, 1996). Ericsson, Krampe and Tesch-Römer (1993) have suggested that the study of expert performers and their teachers offers an almost untapped reserve of knowledge about optimal training and training methods.

In professional learning, the need for a redefinition of expertise has emerged from the rapid changes in work life and social conditions which have taken place during the last decade in the industrialized world. As a consequence of these changes, people less often work at the same task for long periods. This has brought with it a constant obligation to learn the use of new tools, methods, and technical facilities. This in turn involves a continuous challenge to professionals' prior knowledge and competencies. Thus, new definitions of expertise have been offered which emphasise continuous learning. It has been stated that the central determinant of high-level expertise is the subject's continuous surpassing of his/her previous level of knowledge and competence (Bereiter, 2002; Bereiter & Scardamalia, 1993). This kind of surpassing oneself means that persons are continuously working at the limit or developing edge of their competence.

3.4.3 Creativity

Creativity is also a concept which has something in common with wisdom and expertise. Creativity is usually defined as the ability to produce work that is novel, high in quality and task- appropriate (Lubart, 1994, 1999). Productivity, e.g. quantity of creative work, increases rapidly with age, often peaking around the age of forty (Simonton, 1999). However, besides this general trend the exact location of the peak and the rate of change in productivity depend on the domain. For example peak productivity tends to occur early in the career of pure mathematicians, around the age of 30, but later in the careers of historians and philosophers around the age of 50. Although the productivity of creative work typically declines, there are numerous cases of creative work by people in their eighties and older. There are also large inter-individual differences in the change in productivity with age. Changes in intellectual processes and knowledge may be related to changes in creative productivity as well as to changes in the nature of creative work with age.

The cognitive processes involved in creativity include defining and redefining problems, choosing appropriate problem-solving strategies, divergent thinking, and using insight processes to solve problems (Sternberg &

Lubart, 1995, 2001). These intellectual processes involved in creative performance are subject to both positive and negative age influences. On the positive side, problem definition, strategy selection, selective encoding, comparison, and combination can become more efficient with experience (Berg & Sternberg, 1985). Also, dialectical thinking is believed to develop with age (Sternberg & Lubart, 2001). On the negative side are fluid intelligence or fluid abilities such as thinking rapidly and flexibly, divergent thinking, and selective attention which decline with age (Sternberg & Lubart, 2001). However, some or all of these declines are at least partially reversible by intervention (Willis & Schaie, 1994).

3.5 Theories explaining age-related cognitive decline

We have described above the age-related changes observed in the cognitive domain, especially with regard to the information processing needed in everyday life. Salthouse (1991) has presented and analysed five different theories which have been used to explain the age-related decline in the cognitive domain. These declines are in tasks heavily dependent on fluid intelligence, although it is possible that crystallized intelligence has more meaning and impact in daily life, including work life, than do tasks that depend on fluid cognitive functions. The explanatory theories are: (1) environmental changes which can be seen in cohort differences and in other controlled environment comparisons; (2) disuse interpretation; (3) qualitative differences with reference to structures, strategies, and the relations between competence and performance; (4) localization of deficits, especially in memory abilities, reasoning and spatial abilities; and, lastly, (5) reduced cognitive-processing resources. Salthouse also divided these explanations into those having 'distal' effects, (i.e., impact earlier in the life course, perhaps even beginning in childhood), and those having 'proximal' effects, (i.e. impact occurs at the time of task performance). Distal explanations are included in the environmental change and disuse theories. Salthouse (1999) went on to conclude, in a later paper, that these theories explain only a small part of the age-related decline in cognitive abilities when cross-sectional comparisons across different age-groups are made, and do not explain the inter-individual changes in the cognitive domain during ageing. Among the proximal explanations, Salthouse (1999) emphasises the use of less effective strategies in problem solving tasks, attributing their use to a weakening of individuals' basic cognitive processes. Salthouse sees cognitive processing resources or the lack of them as the most important factor explaining age-related cognitive changes. The cognitive processing resources, identified by Salthouse as important in explaining cognitive decline are: difficulties in focusing attention, decrements in working memory and information-processing speed, and general impairment deficits in central executive functioning.

Until the 1990's the age-related decline in cognitive functions was viewed as irreversible. However, Willis and Schaie (1994) presented data that demonstrated that it was possible to improve the cognitive functions of persons over age 65 so that they could achieve a level of cognitive functioning at least equal to a level they had achieved 7 years earlier. Both groups, examined by Willis and Schaie (i.e. those who had remained at the same level and those who had the level they had had 14 years earlier), benefited from training. Approximately two thirds of participants in their study clearly improved their performance. The effects of the training, provided by these investigators, could still be measured 7 and 14 years afterwards (Schaie, 2005; Schaie & Caskie, 2005; Schaie & Willis, 1996; Willis & Schaie, 1994). It should be noted, however, that the effects of training at 7 and 14 years afterwards were seen only in tasks closely resembling those in which they were trained. No positive transfer to other tasks was reported. These findings, although based on a limited set of studies, demonstrate that there is a clear possibility of positively enhancing the cognitive ability of older individuals.

The importance of general intelligence as a strong resource factor for work performance was demonstrated in a study reported by Hunter and Schmidt (1996). They stressed that general intelligence is the dominant determinant of large individual differences in work output on the job, although highly visible individual differences in citizenship behaviour on the job make the intelligence performance relationship harder to observe in everyday life. Over time, the validity of job experience for predicting performance declines, while that of ability remains constant or increases. Hunter and Schmidt (1996) showed, using path analyses, that the major reason for ability predicting performance so well is that higher ability individuals learn more relevant job knowledge more quickly.

Bialystok et al. (2004) sought to determine whether bilingualism advantage functions as a resource slowing the effects of cognitive ageing, especially in older adults. They reported three studies that compared the cognitive performance of monolingual and bilingual middle-aged and older adults on the Simon task. Bilingualism was found to be associated with smaller Simon effect costs for both age groups; bilingual participants also responded more rapidly to conditions that placed greater demands on the working memory. In all cases the bilingual advantage was greater for older participants. The authors concluded that it appears that controlled processing is carried out more effectively by bilinguals and that bilingualism helps to offset age-related losses, at least in certain executive processes. The study by Bialystok et al. (2004) suggested a new approach for increasing cognitive resources in late adulthood through fostering the acquisition of bilingualism early in life, during childhood and adolescence. This appears to be a feasible strategy for dealing with age related cognitive declines, especially in multilingual societies.

The model of selective optimization with compensation (Baltes & Baltes, 1990), attempts to describe and explain how people try to manage the cognitive losses occurring during ageing. Many people have recognized age-related declines in cognitive processes in themselves as they perform different kinds of tasks. In addition to training, to address deficits in the use of information-processing in different fields of everyday life such as work, interest-based activities, voluntary studies, and voluntary work, there are also additional means available to attempt to compensate. For example, Baltes and Baltes (1990) presented a model they had developed which describes a strategy called "The model of selective optimization with compensation". Their model is based on 7 propositions:

1. There are major differences between normal, optimal, and pathological ageing.
2. There is great variability in ageing from individual to individual.
3. There is much latent reserve.
4. There is an age related loss as one nears the limits of those reserves.
5. Knowledge-based pragmatics and technology can offset age-related decline in cognitive mechanics.
6. With ageing the balance between gains and losses becomes less positive.
7. The self remains resilient in old age.

On the basis of the above-described propositions, Baltes and Baltes (1990) developed their model of selective and compensatory optimization. The model has three interacting elements and processes. The first element is selection, which refers to the increasing restriction of one's life world to fewer domains of functioning. This restriction is hypothesized to be function of ageing-related loss in the range of adaptive potential. Although selection means a reduction in the number of high-efficacy domains, it could also involve new or transformed domains and life goals. Selection implies that an individual's expectations are adjusted to permit the subjective experience of satisfaction as well as personal control, e.g. not being controlled by other persons, luck, fate, or God.

The second element, optimization, refers to people engaging in behaviours to enrich their general reserves and to maximize their chosen life courses with regard to quantity and quality. Intervention studies on plasticity have shown that elderly individuals continually implement this optimizing process.

The third element has two components. As proposed by Baltes and Baltes (1990), this element is composed of compensation, as well as selection, and results from restrictions in the range of plasticity. Compensation is necessary when specific behavioural functions are lost or are reduced below the standard required for adequate functioning. This restriction is experienced particularly at a time when situations and goal characteristics require a wide range of activity and a high level of performance. Compensation involves aspects of mind and technology. Baltes and Baltes (1990) emphasized that by using strategies of selection, optimization, and compensation, individuals can contribute to their own successful ageing. The adaptive task of the ageing person is to select and concentrate on the domains that are of high priority, e.g., working and taking care of necessary daily activities, and that involve a convergence of environmental demands and individual goals, skills, and biological resources (Charness, 2000).

These challenges (of cognitive and physical ageing), include growth in some domains, e.g., wisdom, as well as loss in other domains, especially the loss of speed and facility in later life. Declines in some cognitive components, such as speed of activity and speed of processing information, reduce the richness of the cognitive network past middle age, however, other components, such as synthetic thinking and interpersonal wisdom, can increase the richness. Through this process, the ageing individual can build dynamic cognitive networks to meet various complex life challenges.

The range of variation in the cognitive domain is especially broad and pervasive in adulthood, and increases along with the ageing process. At least three processes account for this wide range. First, adults have a wider range of skills at their disposal because they are capable of going all the way from elementary sensorimotor actions to complex abstractions. Second, the high-level abstractions which adults master are especially subject to the influences of culture and education. Third, adults tend to specialize in particular domains, based on their life choices and situations, like entering one job and not another, taking on one hobby and not another, some social roles but not others (Fischer, Yan & Stewart, 2003).

The development of the cognitive domain over the lifespan shows it to be rich and dynamic; a complex web that is constantly changing with multiple levels, strands, networks, and directions. The wisdom and intelligence of an adult cannot be captured by any one developmental level, domain, pathway, or direction. As Fischer, Yan and Stewart (2003, p. 513) conclude "During adulthood, intelligence commonly moves to become more sophisticated, flexible, synthetic, constructive, and socially oriented - more complex and dynamic. Cognitive development in adulthood takes a number of different shapes, and it occurs through a set of fine-graded mechanisms for building and adapting skills. Specific skills emerge at one level but require long periods of consolidation before they predominate in ordinary contexts. They emerge abruptly as new optimal levels for a given domain, but develop more slowly and gradually as functional levels of everyday action". Fischer, Yan, and Stewart (2003) also emphasise the role of learning with others when coping with the challenges of a rapidly changing world, as in the case of today's work life. What is still needed is valid knowledge of what, how, and why cognition changes in adults, in order to help elderly individuals to meet new challenges in their complex living environments, work, and the work environment.

4 COGNITIVE AGEING IN RELATION TO WORK ABILITY

4.1 Threatening and resource factors of work ability

The relationships between age-related changes in the cognitive domain and the Work Ability Index (WAI; Tuomi et al., 1998) are connected to the requirements of the work itself, as well as to the opportunities for development which the work allows, which may vary between occupations and professions. It has been forecasted that in the future many factors will bring about rapid changes in work content, work methods, and the work environment that will necessitate new learning. However, some kinds of expertise will become valueless as occupations vanish as a result of technological innovation.

On the basis of age-related changes in the cognitive domain and on the basis of the expected changes in work life it is possible to identify both the factors which threaten an ageing workers' work ability and those which may support it.

Some threatening factors, for example:

- change in the content of work, as working methods increase in complexity and become more diverse than those previously encountered;
- the need to learn new skills as well as to enhance one's own competencies;
- rapid growth in the importance of abstract thinking, reasoning, decision making and foreign language skills as well as knowledge and understanding of new information technology (NIT);
- increased challenges that occur in acquiring new knowledge and skills;
- increased mental strain, with an increased number of stress factors and time pressure;
- increase in the variety of different employment contracts (e.g. part-time work, temporary work, time-restricted projects, different forms of unemployment and underemployment);
- increase in the importance of the cognitive domain for maintaining work ability in relation to changes in occupations.

In all of these, discussed above, the elderly worker is not as proficient a learner as a younger one, but given time the elderly worker can also successfully cope with these changes, assuming that he/she is also motivated to acquire the new knowledge and skills.

The following changes, are part of the cognitive domain-related competence and resource factors of older workers:

- more freedom in selecting the time and place for work. From the employers' point of view an older worker can be better trusted than a younger worker because of their greater loyalty and effectiveness;
- individual responsibility for work outcomes and services will increase among all workers, but, because older workers are more quality-orientated than their younger counterparts, this change will favour the older worker;
- social skills are higher among older than younger persons.

We have to remember that although the age-related changes in the cognitive domain and in work ability are not unavoidable; both can be affected by many different kinds of successful interventions. Salthouse (1997) has noticed, for example, that older workers can compensate for age-related losses such as the slowing of information processing and psychomotor reactions, by relying on lessons learned over long work experience and by anticipating problems in future situations.

We have seen that during ageing there are large differences in individual age-related changes. These differences in age-related changes can be found in the information-processing abilities of 'healthy' individuals, especially in their central executive functioning skills, which are crucial for cognitive functioning. These changes differ with regards to age of onset, magnitude, and direction, but for the majority, the general trend is one of stability in cognitive functioning until the age of 70. The only exceptions to this general trend are speed-related functions, such as perceptual speed, and complex new tasks which impose high demands, high stress, and which require rapid performance. However, an individual can use his/ her reserve capacities as well as the strategy of selective optimization with compensation so that he/she can still accomplish necessary tasks in the work environment and be successful. It has to be emphasised that the inter-individual differences in age-related cognitive changes and in work ability are much greater than the differences between age-groups on these factors.

4.2 Age-related changes in work ability

The study by Tuomi (1997) has shown that during an 11-year follow-up of work ability, 60 % of subjects remained at the same level, while, it fell among 30 %, and it improved among 10 % even though they aged by a decade. These changes were rather similar across physical, mixed, and mental work, and for both sexes. It is to be noted that these subjects were in the same jobs at both the baseline and at the follow-up phases of the study.

The analysis regarding the possible critical ages of decline in work ability showed that the distribution of men and women scoring in the poor category on the WAI was correlated to both the type of work held and the age of the worker. Workers between the ages of 47 and 51 years did not appear to be in a critical age range where declines would be evident. However, by the age of 52 to 58 years there was a marked decrease in work ability among both men and women as measured by low composite score on the WAI (see pages 8-9). The steepest decline in work ability was found among those workers employed in physically demanding jobs (5–25%), with only a moderate decline, as indicated by a more gently sloping trendline, among those individuals involved in mental work (3–15%) and among those women in mixed work (e.g. nursing) (Ilmarinen, Tuomi & Klockars, 1997; Nygård et al., 1991). It was noted that, as in the case of age-related changes in cognitive functions, inter-individual differences also greatly increased quite dramatically with age.

The above-mentioned results do not differ dramatically much from those results which have been observed in follow-up studies that describe age-related changes in the cognitive domain. Changes in the cognitive domain, however, begin at a later age than decrements noted on WAI, suggesting that work ability may be a more sensitive indicator of incipient cognitive decline. It is only fair to emphasise the importance of speed and attention required in many jobs, especially among blue-collar workers. However, the speed factor has also increasingly begun to affect white-collar professions as fewer personnel are now asked to perform larger amounts of work in a given time-period than, for example, 10 years ago. The effects of this increased work load, can be seen in the increase in reported work load by employees, in the rates of reported feelings of depression, as well as in the number of mental disturbances which result in prolonged sick leave and premature retirement on disability pensions (Nygård, Suurnäkki & Ilmarinen, 1999). Assuming that the role of speed and an increased work load will continue to be important, as employers attempt to lower costs through productivity gains, and that the expertise of the older worker is no longer considered relevant to either changes in work content or methods, it is still possible and cost effective to structure the working environment to better adapt to the resources provided by an older workforce. In such an environment workers can learn new skills as they age, providing they are given the opportunity. Under these conditions it will also be possible to use the model of selective optimization with compensation that was discussed above. In practice this means that the work environment, work organization, work content, and working methods have to be tailored to the resources of an individual. These resources are not stable but can, however, be enhanced through various interventions.

The few studies that have investigated the cognitive components required to be successful in a work environment have shown that it is possible to increase the level of cognitive functioning and decrease or slow down its deterioration. Several intervention studies have shown that work ability can also be positively affected through numerous activities, providing that worker participation is encouraged (Louhevaara et al., 2003). In the studies in which an intervention has shown no significant effects, two explanations have been offered. First, and perhaps most importantly, the content of the interventions has not covered all four crucial dimensions of work ability (i.e., work environment, work community, health, and occupational competence of the individual), the second explanation provided is that the WAI, as an instrument, may not have been sensitive enough to reflect the possible changes due to the interventions (Ilmarinen & Tuomi, 2004).

Because the WAI is based largely on self-ratings (9 items and 57 diseases diagnosed by a physician and/or by the subject) regarding the individual's work ability-related variables, it is also possible that age-related changes in metacognition affect WAI ratings. Changes in metacognition are measured according to the individual's own experiences about how his/her cognitive functioning has changed in relation to an earlier level. However, these metacognition ratings, of how old worker feels, are not based solely on the individual's own experiences and feelings, rather they can also be based on the people with whom they interact with at work, at home, or the people with whom they are interacting with in interest-based activities (e.g. Uotinen, 1998; Uotinen, Suutama & Ruoppila, 2003). If persons important to the subject begin to emphasise age-related changes in the individual's behaviour, it can have an affect on his/her feelings about his/her own ageing. Ageing is not only biologically but also socially mediated. An individual's self perception of aging can be affected by others when they begin to label the person as aged or ageing. In a worst scenario age discrimination or age segregation in the workplace can adversely effect an individuals feelings of competence as well as their self perception of age. Age discrimination or age-segregation subject the worker to a confrontational workplace environment where self worth and esteem can be threatened as well as threatening self perception of social roles and positions outside the work environment. It is not known how important this kind of ageism is as a factor affecting work ability but it can not be excluded. However, ageism is very difficult to study because it is forbidden by legislation in many industrialized countries, also including Finland.

Maurer, Weiss and Barbeite (2003) reported that older workers received less support for development and that they also generally possessed fewer individual development-enhancing characteristics. They reported that perceived relative age was distinguishable from chronological age and was associated with a different set of variables. This may mean that not only are factors associated with being older in an absolute sense important in the work context, but that factors associated with being relatively older also play a role that influences development. Maurer et al. (2003) have discussed whether being older in a young group might lead to less support and encouragement to pursue challenging assignments that require intensive learning, especially if there are younger individuals who might be perceived as more appropriate for such assignments. In their discussion they suggested that attention in the workplace to employees' relative ages and not just to chronological ages should be a concern when addressing possible age bias or discrimination in opportunities for development.

Older workers reported feeling less cognitively able and of having lower perceptions of themselves as possessing learning qualities. This perceived deficit in learning preparedness, as it relates to cognitive processes, is generally consistent with both stereotypes and data on actual age-related changes. For example, perceived relative age was negatively related to perceived intelligence and positively related to perceiving one's mind as having declined. Likewise, chronological age was positively related to declining mind and negatively related to perceptions of possessing learning qualities (Maurer et al., 2003). However, these differences did not seem to handicap older workers in any way in their overall involvement in work. It is important to stress that chronological age had a positive relationship with job involvement and a negative relationship with perceived need for development. This finding implies that consideration of one's career situation involves orientation to one's absolute age or stage in life and that this is less dependent on the characteristics of one's peers or others at work (Maurer et al., 2003). In all, the age effects reported by Maurer and colleagues were relatively small, and there were no indirect effects on entire job involvement. As Maurer et al. (2003) stressed, this is a very important finding to add to the literature, given the stereotype or notion that involvement in learning and development activity declines with age. Maurer et al. used a sample of full-time workers, thus omitting older workers who had left the work force either voluntarily or as a result of being forced out in recent years. The fact that some older workers do not continue to invest in skill development through continuous learning and development, might result in early departure from full-time work for various ancillary reasons. If this was the case, the sample studied may actually underestimate the relationships between age and the other constructs included in their model. Moreover, older workers may also make an active choice to reduce or terminate their involvement in job related learning and development as a direct result of job related ageism or discrimination.

Maurer et al. (2003) have also discussed the problem of demographic variables serving as confounders when examining the performance of older workers. A significant problem exists in attempting to identify and separate the effects of various demographic variables from age related effects that effect worker performance. Maurer and colleagues demonstrated that demographic variables could account for most of the variance in work performance after controlling for factors such as the experiences the older worker had in their job, the type of job that they hold, the number of years that they expect to work before accepting a full retirement, and so forth. Statistical control of all the confounding variables is a very conservative procedure as it removes all the overlap between age and the other variables, regardless of the true underlying causal relationships. Even if age really is a causal agent, the effects of age will be removed if overlapping variables are controlled for. Such statistical control, however, shows that strong conclusions on age related changes being a causal agent cannot definitively be made when other key variables are still confounded with these age related changes, as will usually be the case (Maurer et al., 2003).

Finally, there is a glaring need for studies which simultaneously follow both cognitive age-related changes and their relations to the changes in work ability, as well as how they interact, as both effect the other. Cognitive functions are both practised and trained at work with the result that work stimulates information-processing. The cognitive domain in turn is important in its effects on the work environment, work content, work organization and work methods, e.g. via wisdom and creativity. It is possible that this reciprocal interaction between the cognitive domain and WAI is behind the partially similar age-related changes in both of them.

In our review we have restricted ourselves to analysing the relationships between age-related changes in the cognitive domain and age-related changes in work ability to the so-called normal working population, thus leaving out persons who are not in work life because of their health or for other reasons such as taking care of children, grandchildren, their own parents, or a spouse. Also we have not discussed the connections with people who are unemployed or underemployed (e.g. Elder, 1974; Feather, 1990; Jahoda, 1982, 1988; Kivimäki et al., 2000). These adults are, however, very important as a resource or reserve in the labour market, given that the working population is rapidly ageing, and in most western industrialized countries, decreasing in numbers. It would be essential to know how voluntary and involuntary unemployment and underemployment affect both cognitive age-related changes and age-related changes in work ability. There are many good reasons to expect that in general unemployment and underemployment are devastating living conditions, at least for most adults, in which to seek to keep one's cognitive functioning and work ability intact. This theme merits urgent study in differing conditions of unemployment and underemployment as well as in conditions representative of blue and white-collar employment. This topic has long-term importance for an individual's post-retirement and physical, psychological, and social functioning.

5 WORK ABILITY AND COGNITIVE FUNCTIONS: RESULTS FROM A LONGITUDINAL STUDY

5.1 Research data and subjects

Because the retirement age in Finnish municipal occupations ranged from 53 to 63 years in early 1980ties, the range being now from 63 to 68 years, the question was whether job-dependent retirement ages were still valid. New criteria and concepts for retirement, including aspects of work and work ability were needed. Hence, the Local Government Pension Institution (Kuntien Eläkevakuutus) sponsored this study on ageing municipal employees. Our multidisciplinary research team (occupational physiology, psychology, medicine, epidemiology and biostatistics) started a series of studies among municipal employees in 1981, and repeated them in 1985, 1991 and 1997 (Ilmarinen 1991; Tuomi 1997 .The stress-strain concept (Rutenfranz 1981) was used as the overall framework of the study.

Measurements broadly included work demands and stressors, individual factors and indicators of strain, both subjectively by questionnaire, clinically in laboratories and through observation in the workplace. As one component of the study, laboratory measurements on the physical, social and mental functional capacity of the workers were conducted. Also stress and strain measurements were carried out in the workplace.

In order to compare employees in different occupational groups, we developed the Work Ability Index as a comprehensive measure of work ability. The background, concepts, methods, projects and results of the 4-year follow-up (Ilmarinen 1991) and 11-year follow-up have been published separately (Tuomi 1997). The assessment of the validity and reliability of the Work Ability Index has also been reported (Ilmarinen and Tuomi 2004).

At the beginning of the study in 1981, all the subjects (N=6257) were still active employees (Tuomi et al. 1997). The age range was 44–58 years. In 1985, the subjects were already divided into groups of active workers, retired workers, and deceased persons. In 1992, the subjects were 55 to 69 years old, most of them retired or disabled. Less than 20 per cent had remained at work during the follow-up. In 1997, only a very small fraction was still working.

The participants in the laboratory based functional capacity studies in the laboratory were chosen for the study population by stratified random sampling designed to represent the whole range of municipal occupations in the different regions of Finland. A total of 80 persons; 38 women and 42 men, participated in all three laboratory measurements in 1985, 1992 and 1997. In 1997, the mean age of women was 66.7 years and of men 67.9 years.

Compared to the original cohort, the follow-up cohort contained more men (52 % vs. 44 %), and more persons in mental occupations (65 % vs. 30 %). In the latter group, work ability was also better among the participants of the laboratory measurements (WAI mean 38.6 vs. 35.3). More information on the selection of the subjects is given by Suvanto et al. (1991), who has previously reported selective cognitive changes over 4 years in some cognitive functions and by Savinainen (2004) who described the changes in physical capacity with the same participants over a 16-year-follow-up with reference to the same subjects.

In this study, two data sets were used (Table 6.). The first consisted of those who attended the laboratory tests and were also occupationally active from 1981-1985 (n=68). The second dataset contained the subjects who replied to the questionnaires in 1981-1997, and who remained at work until 1992 (n=717). This cohort was used in the multivariate analyses of self-rated functioning.

5.2 Methods

Work Ability Index

Work ability was measured by a questionnaire. The work ability index (WAI) was derived as the sum of the scores of seven items and the range of the scores of the index was 7-49 (see Appendix 1; Ilmarinen et al. 1997, Tuomi et al. 1998). Information on the validity and reliability of the WAI has been published earlier (see Figure 2, and Tables 2 and 3).

Measured cognitive functions (MCF)

Since 1985, five subtests from the Wechsler Adult Intelligence Scale (WAIS) have been used (Eskelinen et al. 1991, Suvanto et al. 1991). *Verbal concept formation* was measured with the Similarities subtest, *visuo-constructive ability* with the Block Design subtest, *visuo-motor speed* with the Digit symbol subtest, *auditory short-term memory and concentration* by the Number repetition subtest (Digit Span, Numbers forward and backward), and *basic perceptual and conceptual abilities* with the Picture Completion subtest. In addition, *visual speed and accuracy* was measured with a Bourdon-type Letter Cancellation test (NJEVD). The task was to search through rows of letters on a standard-sized

(A4) sheet of paper and cancel one of the five target letters within 5 minutes. Both the number of the letters found and errors were calculated.

TABLE 6 Gender distributions (%) in the original questionnaire and in the cognitive functioning cohorts (MCF) and in the follow-up datasets in this study, by the type of work

	Physical work	Mixed work	Mental work	All
Original cohort	(n=2648)	(n=1907)	(n=1702)	(n=6257)
Men	49	25	26	45
Women	37	35	28	55
Original MCF cohort	(n=57)	(n=25)	(n=68)	(n=150)
Men	37	19	44	49
Women	39	14	47	51
Study dataset	(n=331)	(n=228)	(n=457)	(n=1016)
Men	39	16	45	39
Women	28	27	45	61
MCF follow-up dataset	(n=15)	(n=9)	(n=44)	(n=68)
Men	14	14	71	51
Women	30	12	58	49

The test scores of the above subtests were standardized (mean 0, standard deviation 1) and the measured cognitive functions' (MCF) scale was formed by summing the items. The range of the scale was 18–10. The reliability indexes (Cronbach α) of the scales in 1985, 1992 and 1997 were 0.82, 0.85, and 0.84, respectively.

Self-rated cognitive functions (SCF)

In the questionnaires, several items of self-rated cognitive functions were included. The question was: "How do you evaluate yourself according to the following characteristics?" (1 = weak, 2 = somewhat weak, 3 = satisfactory, 4 = good, 5 = very good). The following three items were selected for this article: reaction capacity, memory, and sense of comprehension. A composite measure of these items was constructed. The reliability indexes (Cronbach α) of the scales varied from 0.82 (1985) to 0.81 (1992 and 1997). The scale range for this composite measure was 2–15.

Type of work and other background variables
On the basis of an analysis of job content and demands, three groups were formed using the AET method, (Ilmarinen et al. 1991): physically demanding work, mixed physically and mentally demanding work, and mentally demanding work (Tuomi et. al 1997). Gender and age were included in the analyses.

Statistical methods
Time-related differences in the measured cognitive functions, self-rated cognitive functions, and work ability were assessed by tests of mean differences and by F-tests.

The associations between the psychological tests, self-rated cognitive functions, and scores from the work ability index were assessed with the Pearson correlation coefficients, and with cross-lagged correlations (AMOS statistical package).

The effects of self-rated cognitive functions in 1985 on work ability in 1992, and, correspondingly, the effects of work ability in 1981 on self-rated cognitive functions in 1997 were analyzed with general linear models. Gender, age and type of work were included in the model.

5.3 Results

5.3.1 Changes in cognitive functions and work ability

Measured cognitive functions (MCF)

On average, the individual WAIS scores decreased from 1985 to 1997 with the exception of the number repetition tests. This trend was obvious among men and women and in all occupational groups (Tables 7 and 8). The gender differences were seen in the Picture Completion and Block Design tests, which favoured men, and in the NJEVD, which favoured women. In addition, the scores in the MCF scale indicated that men had higher cognitive capacity than women. However, none of these results proved to be statistically significant.

In all the measurements, the level of WAIS test scores was highest in the mental work group (Table 8). Specifically, the Similarities and Digit symbol subtests favoured mental work. The differences between the three categories of work were emphasized in the MCF scale. The largest drop in the MCF scale (the score halved from 1985 to 1992) was among those doing physical work. In the other groups, the decrease was less dramatic.

TABLE 7 Means and standard deviations (SD) of the raw scores of WAIS subtest and of the standardized MCF scale for the follow-up subjects (n=68) in 1985, 1992 and 1997 by gender

Test	Range	Men (N=35)						Women (N=33)					
		1985		1992		1997		1985		1992		1997	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Similarities	0–26	22.0	3.7	21.2	3.9	19.7	4.3	19.4	6.0	19.5	5.3	18.5	6.1
Number repetition													
Backwards	2–7	4.4	1.0	4.4	1.0	4.4	1.2	4.4	1.0	4.4	0.9	4.6	1.0
Forwards	4–8	5.7	0.8	5.6	1.0	5.6	0.9	5.6	0.9	5.7	0.9	5.8	1.0
Digit symbol	14–74	45.7	13.4	43.8	12.2	40.4	12.5	45.1	12.9	42.3	11.0	39.6	11.8
Picture completion	1–21	15.2	2.6	15.3	3.3	14.1	2.6	12.9	3.6	12.8	3.5	11.6	3.2
Block design	10–57	36.6	7.7	33.9	8.2	32.9	9.6	32.8	9.0	31.1	8.1	30.8	8.7
NJEVD	169–1050	521.8	174.8	431.0	144.9	467.5	220.9	560.3	173.8	472.2	162.5	473.9	150.5
MCF scale	-14.1–10.1	2.54	4.0	1.59	4.7	1.07	4.9	1.09	4.4	0.44	4.6	0.12	4.6

TABLE 8 Means and standard deviations (SD) of the raw scores of WAIS subtest and of standardized MCF scale for the follow-up subjects (n=68) 1985, 1992 and 1997, by type of work (physical work, mixed physical and mental work, and mental work)

Test	Physical (N=15)						Mixed (N=9)						Mental (N=44)					
	1985		1992		1997		1985		1992		1997		1985		1992		1997	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Similarities	16.4	7.9	16.7	5.5	14.6	6.8	17.2	4.3	18.3	6.1	17.0	6.2	22.9	2.2	22.1	2.8	21.1	2.9
Number repetition																		
Backwards	4.1	1.1	3.8	0.9	4.0	1.1	3.9	1.1	4.0	1.3	3.9	1.4	4.6	0.9	4.7	0.8	4.8	0.9
Forwards	5.4	0.7	5.1	0.8	5.5	0.6	5.3	0.7	5.3	1.1	5.3	0.7	5.9	0.9	5.9	0.9	5.9	1.1
Digit symbol	36.9	11.4	34.9	9.5	32.0	13.3	33.2	12.1	34.8	11.2	29.9	8.6	50.9	10.4	48.0	9.5	44.8	9.4
Picture completion	12.4	4.0	11.7	4.6	10.5	3.9	13.8	2.9	12.0	3.6	12.3	3.0	14.7	3.0	15.4	2.4	13.8	2.4
Block design	29.9	9.4	27.3	7.9	27.3	9.1	27.9	7.5	28.7	11.1	24.9	11.3	37.8	6.9	35.2	6.4	35.0	7.2
NJEVD	482.2	131.2	403.8	172.4	390.1	157.8	432.2	193.8	334.3	129.1	384.8	147.3	582.5	170.8	496.5	134.2	515.7	193.5
MCF scale	-1.56	4.4	-3.03	4.3	-3.26	4.7	-2.11	3.8	-2.49	5.5	-2.94	5.3	3.80	2.8	3.24	2.9	2.65	3.2

TABLE 9 Means and standard deviations (SD) of the self-rated cognitive functions (SCF) and of the cognitive function scale for the follow-up subjects (n=68) in 1985, 1992 and 1997, by gender

		Men (N=35)						Women (N=33)					
Item	Range	1985		1992		1997		1985		1992		1997	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Reaction capacity	1–5	3.4	0.8	3.4	0.7	3.4	0.7	3.0	0.9	3.1	0.6	3.3	0.8
Memory	1–5	2.8	0.9	3.0	0.8	3.1	0.9	2.9	1.0	2.9	0.7	2.9	0.8
Sense of comprehension	1–5	3.4	0.8	3.3	1.0	3.4	0.9	3.4	0.8	3.2	1.0	3.5	0.8
Cognitive function scale	1–15	9.5	2.3	9.6	2.3	9.9	2.2	9.1	2.6	9.0	2.0	9.5	2.2

TABLE 10 Means and standard deviations of self-rated cognitive functions (SCF) for the follow-up subjects (n=68) in 1985, 1992 and 1997 by type of work (physical work, mixed physical and mental work, and mental work)

	Physical (N=15)						Mixed (N=9)						Mental (N=44)					
Function	1985		1992		1997		1985		1992		1997		1985		1992		1997	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Reaction capacity	2.8	0.9	3.2	0.7	3.4	0.7	2.9	1.0	2.9	0.9	3.1	0.9	3.4	0.8	3.3	0.6	3.4	0.7
Memory	2.5	1.0	2.8	0.9	2.8	0.9	2.6	1.1	2.1	0.9	2.9	1.1	3.0	0.9	3.1	0.6	3.0	0.8
Sense of comprehension	3.1	0.5	2.9	0.9	3.2	0.6	2.8	0.7	2.6	1.1	2.8	1.0	3.6	0.8	3.5	0.9	3.7	0.8
Cognitive function scale	8.4	2.2	8.7	2.1	9.0	1.9	7.7	2.7	7.6	2.8	8.8	2.9	9.9	2.3	9.8	1.9	10.1	2.1

TABLE 11 Means and standard deviations (SD) of Work Ability Index for the follow-up subjects in 1981, 1985 and 1992 by gender and type of work

	1981			1985			1992		
Factor	Mean	SD	N	Mean	SD	N	Mean	SD	N
Men	39.3	6.6	34	37.3	6.3	33	35.3	7.9	10
Women	37.9	7.3	30	33.2 *	6.6	35	35.8	6.9	12
Physically demanding	35.3	7.9	14	31.8	7.4	15	-	-	3
Both physically and mentally demanding	36.4	5.3	9	35.6	5.9	9	-	-	1
Mentally demanding	40.3	6.4	41	36.4 **	6.4	44	35.4	7.1	18

* $p < 0.05$; ** $p < 0.0$

1

Self-rated cognitive functions (SCF)

The change in the pattern of SCF did not follow that of the MCF. In contrast to the decrease in MCF, there was an increase noted in SCF scores between 1985 and 1997 (Tables 9 and 10). The overall trend was clearest in the cognitive function scale: the average level increased in both gender groups and in all three work content groups. However in the mental work group, the level of SCF was highest (corresponding to the results for MCF) and the increase smallest (lowest) between 1985 and 1997, indicating a narrowing of the differences between the work content groups (Table 10).

Changes in the Work Ability Index

The Work Ability Index score decreased from 1981 to 1985, among both men and women, in all types of work (Table 11). The decrease was striking in women, amounting to almost five points (from 37.9 to 33.2, $p < 0.01$) or about 0.7 SDs. Also, the decrease in mental work (from 40.3 to 36.4) was statistically significant. The amount of data for 1992 was limited because of the numbers of participants transitioning to retirement. The numbers of study participants retiring peaked by 1985 and remained high through the end of the study, especially among those participants doing physically demanding work (Table 11).

5.3.2 The relations between WAI and cognitive functions

The correlations between cognitive functions and the Work Ability Index (research questions 2 and 3) were overall quite modest but positive (tables 12-15). There were some striking differences between the groups. Among women, the correlation between WAI in 1981 and measured cognitive functions in 1997 was 0.54, but among men it was only 0.05 (Table 12). This gender difference in correlations was not seen in MCF in 1985. In physical work, the correlation between WAI in 1981 and MCF in 1997 was 0.38 (Table 13). In the other two groups, the correlations were close to zero.

TABLE 12 Correlations and their statistical significance between the Work Ability Index (WAI) in 1981 and 1985, WAIS tests, and MCF scale in 1985 1992 and 1997, by gender

Test		Men (N =35)		Women (N=33)	
	Year	WAI 81	WAI 85	WAI 81	WAI 85
Similarities	1985	0.11	0.14	0.36	0.17
	1992	0.09	0.14	0.21	0.15
	1997	0.04	0.07	0.46 *	0.30
Number repetition					
backwards	1985	0.05	0.18	0.09	- 0.17
	1992	- 0.05	- 0.13	- 0.02	- 0.07
	1997	- 0.05	0.06	0.28	0.45
forwards	1985	0.24	0.23	0.21	0.05
	1992	0.21	0.22	0.16	0.19
	1997	0.19	0.10	0.29	0.20
Digit symbol	1985	0.38*	0.25	0.35	0.29
	1992	0.05	0.08	0.39*	0.30
	1997	- 0.06	0.06	0.49**	0.40*
Picture completion	1985	0.04	0.08	0.10	0.03
	1992	- 0.02	- 0.07	0.30	0.18
	1997	- 0.12	0.08	0.40*	0.23
Block design	1985	0.26	0.01	0.11	0.08
	1992	- 0.04	- 0.07	0.12	0.18
	1997	0.09	0.02	0.22	0.18
NJEVD	1985	0.08	0.04	0.30	0.27
	1992	0.05	- 0.03	0.49**	0.30
	1997	0.17	0.28	0.52**	0.31
MCF	1985	0.27	0.22	0.34	0.16
	1992	0.05	0.02	0.35	0.26
	1997	0.05	0.14	0.54**	0.42*

*: $p < 0.05$; **: $p < 0.01$

TABLE 13 Correlations and their statistical significance between the Work Ability Index in 1981 and 1985, WAIS tests, and MCF scale in 1985, 1992, and 1997, by type of work

Test		Physical (N=15)		Mixed (N=9)		Mental (N=44)	
	Year	WAI 81	WAI 85	WAI 81	WAI 85	WAI 81	WAI 85
Similarities	1985	0.32	0.16	- 0.10	- 0.12	- 0.03	0.13
	1992	0.27	0.34	- 0.30	- 0.12	- 0.03	- 0.03
	1997	0.49	0.42	- 0.61	- 0.57	0.13	0.09
Number repetitions							
backwards	1985	- 0.26	- 0.49	0.01	0.29	0.13	0.08
	1992	- 0.20	- 0.38	- 0.14	0.18	- 0.18	- 0.28
	1997	- 0.01	0.21	- 0.29	0.06	- 0.01	0.12
forwards	1985	0.37	0.01	0.34	0.40	0.07	0.08
	1992	0.09	0.01	0.11	0.48	0.08	0.05
	1997	0.43	0.14	0.21	0.10	0.08	0.04
Digit symbol	1985	0.15	0.25	0.26	0.38	0.29	0.12
	1992	0.06	- 0.09	0.04	0.19	0.08	0.16
	1997	- 0.20	0.27	0.21	0.32	- 0.12	0.03
Picture completion	1985	- 0.02	0.15	0.28	0.22	- 0.02	0.02
	1992	- 0.15	0.06	0.51	0.16	- 0.20	0.04
	1997	- 0.20	0.02	0.24	0.26	- 0.04	0.24
Block design	1985	- 0.01	0.12	0.13	- 0.11	0.06	- 0.02
	1992	- 0.01	0.17	- 0.09	- 0.29	- 0.13	0.01
	1997	0.05	0.13	0.08	- 0.01	0.02	0.01
NJEVD	1985	- 0.45	- 0.25	- 0.23	0.29	0.30*	0.10
	1992	0.07	- 0.10	0.26	0.08	0.23	0.11
	1997	0.42	0.30	0.10	0.38	0.17	0.17
MCF	1985	0.02	- 0.01	0.14	0.36	0.26	0.15
	1992	0.12	0.04	0.05	0.11	- 0.03	0.01
	1997	0.38	0.33	- 0.06	0.05	0.06	0.18

*: $p < 0.05$;

5.3.3 Cross-lagged correlations between Work Ability Index and cognitive functions

Cross-lagged correlation coefficients were calculated between WAI test scores and the individual MCF tests and MCF scale over the time period from 1985 to 1997. None of these correlations was statistically significant, indicating that neither WAI nor MCF in 1985 predicted MCF or WAI in 1997.

There were weak to moderate correlations between WAI scores in 1981 and 1985 and the self-rated cognitive functions in all three measurements (i.e. reaction capacity, memory, and sense of comprehension). This relationship was observed for both gender groups and in two types of work (i.e., physical, although only one significant correlation, and mental). (Tables 14-15). The correlations within the gender groups were very similar, the coefficients varying between weak and moderate. However, the analyses indicated greater variation in relation to the type of work among the different groups. These differences may be due mainly to the restricted sample in the physical and mixed categories of work.

TABLE 14 Correlations and their statistical significance between the Work Ability Index in 1981 and 1985, SCF items, and SCF scale in 1985, 1992, and 1997, by gender

Item		Men (N=35)		Women (N=33)	
	Year	WAI 81	WAI 85	WAI 81	WAI 85
Reaction capacity	1985	0.27	0.41*	0.31	0.35*
	1992	0.20	0.24	0.19	0.19
	1997	0.21	0.41*	0.23	0.31
Memory	1985	0.26	0.45**	0.40*	0.49*
	1992	0.32	0.38*	0.43*	0.42*
	1997	0.17	0.53**	0.38*	0.49*
Sense of comprehension	1985	0.30	0.38*	0.34	0.36*
	1992	0.30	0.33	0.40*	0.33
	1997	0.20	0.40*	0.29	0.30
SCF-scale	1985	0.24	0.44**	0.39*	0.47**
	1992	0.31	0.37*	0.40*	0.34
	1997	0.22	0.51**	0.30	0.40*

*: $p < 0.05$; **: $p < 0.01$

TABLE 15 Correlations and their statistical significance between the Work Ability Index in 1981 and 1985, SCF items, and SCF scale in 1985 1992 and 1997, by type of work

Item		Physical (N=15)		Mixed (N=9)		Mental (N=44)	
	Year	WAI 81	WAI 85	WAI 81	WAI 85	WAI 81	WAI 85
Reaction capacity	1985	0.25	0.43	0.04	0.39	0.27	0.36*
	1992	0.01	- 0.08	0.25	0.43	0.22	0.31*
	1997	0.05	0.25	0.21	0.61	0.28	0.36*
Memory	1985	0.14	0.52*	0.28	0.60	0.33*	0.33*
	1992	0.40	0.39	- 0.11	0.01	0.38*	0.47**
	1997	0.30	0.52	- 0.05	0.48	0.31	0.52***
Sense of comprehension	1985	0.06	0.47	- 0.07	- 0.12	0.32*	0.36*
	1992	0.20	0.23	- 0.06	0.09	0.39*	0.36*
	1997	0.02	0.10	0.07	0.44	0.20	0.34*
SCF-scale	1985	0.18	0.53	- 0.05	0.34	0.32*	0.42*
	1992	0.19	0.15	0.02	0.18	0.39*	0.44**
	1997	0.04	0.34	0.07	0.52	0.29	0.46**

*: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$

To get some indication of the possible causal relations between the Work Ability Index (WAI) and self-rated cognitive functioning (SCF), cross-lagged correlations were used. According to the model (Figure 4), WAI and SCF correlated in both 1985 and 1992, although the correlation was higher in 1992. There was also a significant cross-lagged correlation between WAI in 1985 and SCF in 1992 ($r=0.11$, $p < 0.05$) indicating that earlier level of work ability had a weak impact on later self-rated cognitive functions (Figure 4).

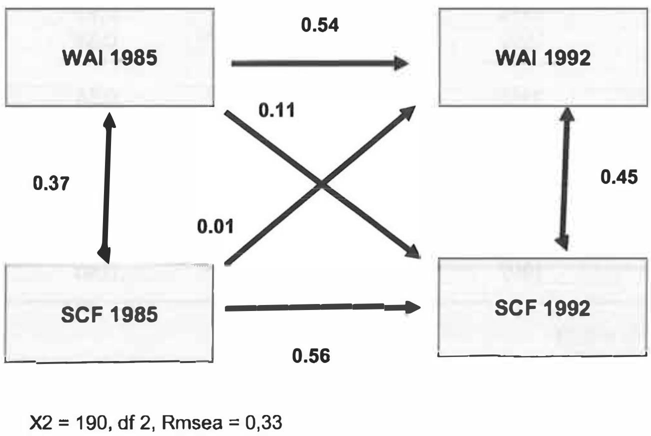


FIGURE 4 Crossed-lag correlations between the Work Ability Index (WAI) in 1985-92 and self-rated cognitive functions (SCF) in 1985-92

The results of the general linear models describing the effect of SCF on WAI are presented in table 16. During the analysis all the first order interactions were tested but none of these were found to be statistically significant.

The results show that cognitive functions had a significant impact on work ability. The estimate value (1.11) indicates the effect of a one-point increase in cognitive functions on the average level of the work ability index. Both the physical and mixed types of work had a negative effect on work ability compared with mental work.

TABLE 16 Results of general linear model for the effects of gender, type of work and cognitive functioning on the Work Ability Index in 1992, (N=717).

Predictor (1985)		Estimate	Standard Error	Chi-square
Intercept		23.9	1.38	
Gender	female	- 0.18	0.48	0.14 ns
	male	0		
Type of work	physical	- 2.67	0.55	23.5 ***
	mixed	- 1.83	0.59	9.6 **
	mental	0		
Self-rated cognitive functioning 1985		1.11	0.13	79.1 ***

*** $p < 0.001$, ** $p < 0.01$, ns not significant

During the analysis all the first order interactions were tested but none were statistically significant. The results indicate that work ability had a significant predictive value regarding the measured cognitive functions after the sixteen-year follow-up period (Table 17). The value estimate of the work ability index (0.05) indicates the effect of a one-point increase in the index on the average level of cognitive function. Both the physical and mixed types of work had a negative effect on cognitive function compared with mental work. Female gender had a positive impact and age a negative impact on cognitive function.

TABLE 17 Results of general linear model - the effects of gender, type of work and Work Ability Index on self-rated cognitive functioning in 1997, (N=717).

Predictor		Estimate	Standard Error	Chi-square
Intercept		11.63	0.71	
Gender	female	0.33	0.07	20.5 ***
	male	0		
Type of work	physical	- 1.18	0.09	171.9 ***
	mixed	- 0.35	0.09	15.2 ***
	mental	0		
Age		- 0.06	0.01	31.1***
Work Ability Index 1981		0.05	0.01	105.3 ***

***$p < 0.001$

6 DISCUSSION

The aim of the study was to find out possible age-related changes in individuals using the Work Ability Index and cognitive tests. We were also interested in discerning both cross-sectional and longitudinal relations between the two sets of variables during the 11-year follow-up. We were particularly interested in assessing the differences between and among men and women, and among different types of works, e.e., physically demanding, both physically and mentally demanding, and mentally demanding. The hypotheses were based on the literature review. It was predicted that both the WAI scores and cognitive functions would decrease at approximately the same rate during the 11 year study period. The changes, however, were greater in the WAI scores than among the various cognitive functions tested. It was also hypothesised that those cognitive functions, being more similar to fluid intelligence, would deteriorate more over time than those cognitive functions associated with crystallized intelligence (Cattell 1971). Further, it was predicted that the changes in WAI scores would be more strongly correlated with the level of self-rated cognitive functions than with the level of experimenter measured cognitive functions, because WAI also is based on self-ratings and thus both have common method variance. Finally, it was expected that there were reciprocical relationships between the WAI scores and cognitive functions so that they longitudinally would be predictive of each another.

These findings are based on the longitudinal studies of ageing municipal employees. This study began in 1981 when all subjects (N=6257) were active employees (Tuomi et al. 1997), with ages ranging from 44 to 58 years. The follow-up assessments were made in 1985, 1992, and 1997. By 1985, the subjects were already divided into groups of active workers, retired workers, and deceased workers, and by 1992, the participants, now aged 55 to 69 years, and were primarily retired or disabled. Less than 20 per cent of the sample had remained active at work during the entire follow-up period. In 1997 the average age of women who participated was 66.7 years and the average age of the men was 67.9 years. In 1999 only a few of these participants were still working. At the end of the follow-up in 1997 there were more men than women (52 % vs. 44

%) and more participants in mentally demanding than in physically demanding occupations (65 % vs. 30 %) still working.

In this study two datasets were used. The first consisted of those subjects who replied to the questionnaires from 1981 through 1997, and who remained at work until 1992 (n=717). The second data set consisted of those who attended the laboratory tests and were also occupationally active from 1981 through 1985 (n=68). The participants of the laboratory examinations for this report were chosen from the study population by stratified random sampling designed to represent the entire range of municipal occupations in the different regions of Finland. Altogether, 80 individuals, 38 women and 42 men, participated in all three laboratory measurements i.e., 1985, 1992, and 1997. The scores of the WAI were higher among those individuals who were assessed in the laboratory (WAI mean 38.6 vs. 35.3). More information on the subject selection has been provided by Suvanto et al. (1991), who have reported on selected cognitive functions over a 4 year time frame, and also by Savinainen (2004) who analysed the changes in physical capacity, for the same subjects' pool, over a 16-year-follow-up.

The measures included the Work Ability Index (Ilmarinen et al. 1997; Tuomi et al. 1998) and in addition five subtests of the Wechsler Adult Intelligence Scale (Similarities, Block Design, Digit Symbol, Digit Span, and Picture Completion, and the Bourdon-type of Letter Cancellation test, NJEVD). Also self-ratings concerning the level of own cognitive functioning was used. These included self ratings of reaction capacity, memory, and sense of comprehension. On the basis of single test scores and from the self-ratings provided by participants, standardized sum-scores were calculated for measured cognitive functions (MCF) and self-assessed cognitive functions (SCF).

The reliabilities of the WAI were above 0.80. Also all the tests as well as self-ratings had the reliabilities over 0.80. Thus the reliabilities are high enough at least for group comparisons.

Age related declines in the WAI were measured between 1981 and 1985 for both among men and women across all occupational categories (Ilmarinen 1997; Ilmarinen et al. 1999; Ilmarinen & Tuomi 2004). Even though age related declines were found for both males and females, the decline was more striking among females. Further the decrease in mental work was significant. The actual number of subjects who were working in 1992 was limited because of the number of participants who had been retired, especially among those involved in physically demanding work.

The measured cognitive functions (MCF) among this cohort also decreased between 1985 and 1997 with the exception of the Digit Span test. This finding was also seen among both men and women. However, even though differences in performance were found, statistically they were not significant, thus demonstrating the stability of cognitive functions over the last 10 to 15 working-career years. We acknowledge that the lack of a difference does not indicate that there was no effect. If we adopted that position we would be accepting the untenable position that we had proved the null hypothesis. It is possible that the lack of difference could be explained by a lack of power, a function of the small number of the subjects examined in the laboratory. It is instructive to note that the standard deviations of the test scores varied considerably, indicating great variation between the subjects. The performance declines over the time course studied, were more evident in the tests which we considered measures of fluid intelligence (Digit Symbol, NJEVD), while in the other tests the decline in performance was rather small. This finding is similar to those in most longitudinal studies including subjects of similar age ranges (Ackerman & Rolfhus, 1999; Baltes, 1993; Kaufman 2001; Laursen 1997, Schaie 1996, 2005).

Gender differences in cognitive functions were not significant, although men scored higher on the Similarities, Picture Completion and Block Design tests than did women, with women scoring higher than men on the NJEVD test (i.e., a test for visual speed and accuracy). It should be noted, however, that some studies have reported that women score higher on verbal tests while men score higher in visuo-spatial tests which was not the trend, though small, in this study. It is possible that our data is biased towards men working in mentally demanding jobs. The men in occupations requiring mental work had more education than did women in the same work content group. This bias, towards more education among the males, might partially explain their higher participation rate in the laboratory study and explain their motivation to try harder to excel in the examinations.

The tests used to assess cognitive functioning in this study measured both crystallized intelligence (Similarities) and in part fluid intelligence (Digit Symbol, Picture Completion, Block Design and NJEVD). In addition, a short-term memory test Digit Span (number repetition forwards and backwards), was included. Thus, in the total MCF score, although a standardized one, the tests assessing fluid intelligence have the largest weight. Also, it should be remembered that all tests except for the short-term memory test, were timed. Thus the standardized scores resulting from the raw scores are affected by the speed of the participant, which is an important factor in all tests assessing fluid intelligence.

In the baseline, and for all follow-up assessments, the WAIS test scores were highest in the work group who were employed in positions requiring mental workloads. Specially, high test scores on the Similarities and Digit Symbol tests occurred among those in positions requiring mental workload suggesting that verbal skills and visual speed and accuracy are higher among this work group than with others. Furthermore, the standard deviations of the MCF were smallest in the mental work group indicating that this group was a strongly selected one. The subjects employed in physical work had lower scores than other participants in both verbal skills and in basic perceptual and conceptual abilities. The sum-score of the WAIS subtests emphasised the differences between the three categories of work. The largest drop in the MCF was among those doing physical work. In other groups this decline was less abrupt. The educational demands and training of people doing mental work are higher and the possibilities for training during a working career are better than in other work groups. Moreover, the mental work necessitates the use of different cognitive functions in work, thus preventing or at least slowing the decrease.

The important finding that replicates previous work i.e. the WAI begins to decrease in late middle-age, but the decrease of MCF begins later and is clearly slower among those who are still working, especially among those doing mental work. In this context it is important to emphasize during the school years beginning of a self-selection process for different training careers based on cognitive ability and performance. This selection eventually affects the health and physical functioning, as well the psychological and social functioning of those entering differing occupations and tends to favour those doing mental work. However, since so many factors have affected the earlier life trajectory of those who enter a mental, a mixed, or a physical work group, it is very difficult to discriminate the effect of an individual's work content on their WAI or MCF performance.

Interestingly, the measured (MCF) and self-rated (SCF) cognitive functions seem to follow a different pattern of age-related change. The measured (objective) changes support, although weakly, the decline hypothesis, especially in subtests other than the short-term memory test. Self-rated cognitive functions, characterized as metacognitions, increased during the sixteen-year follow-up that we conducted. This can not be explained totally by selection, i.e. "healthy worker effects", as the same effect should also hold for MCF. It is plausible that our finding could be explained by the SOC theory discussed in chapter 3. Elderly people make social comparisons, and adjust their subjective evaluations and level of aspiration in relation to their current life environment and the daily tasks they execute after leaving their cognitively more demanding work life. Also, they relate these comparisons to age-mates, many of whom have already either dead, been disabled, or suffer from more serious illnesses and traumas than the rater. This relationship has been shown in studies on diagnosed diseases and subjective evaluations of health and functional capabilities (Fromholt & Berg, 1997; Ruoppila & Suutama 1997a, b; Weinert, 1986).

The follow-up study design, with both measured (objective) and self-rated (subjective) indicators of cognitive functions, allows a unique opportunity to analyze changes and correlations between work ability and cognitive capabilities among the ageing working population. However, the basic question of what impact cognitive demands at work have on the development of workers' cognitive functions across age, has only been partially addressed by this study. Unfortunately, our measures of cognitive functioning are not representative of the universe of functions in of the cognitive domain. Instead, our classification of occupations is based on the experts' ratings taking into account the participants' own evaluations of their work activity.

For the classification of occupations the so called ergonomic job analysis procedure, Arbeitswissenschaftliche Erhebungsverfahren zur Tätigkeitsanalyse (abbreviated AET method in German) was used (Ilmarinen et al. 1991). Altogether 88 job titles and 216 items per job were classified by a trained expert.

By cluster analysis, 13 occupational groups were formed according to the content and demands of the jobs (like auxiliary work, installation work, office work etc.). Because of the small number of persons participating in cognitive testing, a further classification of work into three types of content, i.e., physical, mixed and mental were carried out. This level of gross classification may have impacted on our findings due to the lack of precision that we sought.

With respect to the differences in procedures that we used, the changes in workers´ reported perceptions of their work seemed to be greater than the changes found as a result of the job analyses conducted by the researchers. Job ratings by experts revealed that there were no notable changes in work demands that occurred in the sample of municipal workers in Finland during the study period (Nygård et al. 1999). However, the questionnaire administered to those who remained in the same job from 1981 to 1992 (N=924) revealed that self-rated physical and mental work demands increased during that period. Older workers appeared to work at a relatively higher capacity than younger workers. Changes in stress symptoms were associated with changes at work in that, in general, the greater the increase in the symptoms, the greater the changes in work (Huuhtanen et al. 1997). On the other hand, workers' perceptions of their opportunities for development seemed to increase with age (Nygård et al. 1997). These were measured by using single items with no earlier reliability and validity data. However, these ratings were reliable enough for the statistical analyses of group comparisons.

The metacognitions assessed in this longitudinal study included subjects' self-ratings of their reaction capacity, memory and sense of comprehension. In our data the correlations between measured and self-rated cognitive functions were positive but low. One hypothesis for these low correlations is that self-ratings tend to be based on cohort equivalent comparisons rather than on the individual's earlier performance (Fromholt & Berg, 1997; Ruoppila & Suutama 1997a, b). Practically no age-decline gender differences emerged in the self-rated metacognitions.

The question addressed by the present study was how the different cognitive assessments as well as metacognitions would be related to WAI scores in a follow-up study. The findings supported our predictions that here would be a mutual interaction between measured cognitive functioning and WAI scores. However, the type of work moderated this relationship. The physical and mixed types of work were detrimental for both the cognitive functioning and WAI scores.

The cross-lagged correlations between WAI and SCF were lower than expected, especially the level of SCF which failed to be predictive of WAI scores. The explanation for this may be that adequate cognitive capacities are necessary for staying at work and consequently, the variation of SCF between the subjects was small among the subgroup of active workers.

Our results can be interpreted to indicate that in order to keep both cognitive functioning and work ability as high as possible, the working environment and the work itself should include characteristics of occupations that involve mental work. In particularly this means that the work people do should include the possibility for learning new skills, for gaining autonomy in decisions, for influencing one's own work, and for enhancing well-being. The work environment should be structured, such that there is not too high a level of stress and that the employee feels satisfaction with both their supervisors and their colleagues.

The organizational climate is also important for well being. Although the working conditions and the work were satisfactory for employees involved with the type of work involving mental content, ageing can degrade those perceptions, and may bring with it a lower work ability (Herno et al. 2000). This relationship was apparent in the follow-up study even though the score on the WAI in mentally demanding work was systematically higher than the score from workers in the physical or mixed work content groups, in which across all measurement points, it systematically decreased with age. Work alone does not prevent work ability from declining in any occupation (Ilmarinen et al. 1997). A recent field experimental study, using both an intervention and control group noted that participation in a workplace health promotion programme actually prevented a decline in WAI scores for the intervention group but not for the controls (Elo et al. 2004).

What are the most important factors, besides age, in both the mixed and physical types of work content that affect WAI scores? It can be argued that a working environment which includes factors detrimental to health will reduce work ability, because both objective and self-rated health play an important role in work ability. Many different factors may operate at the same time to cause a detrimental work environment. These factors can include noise, impurities in the air, heavy lifting without proper aids, temperature extremes, and unhealthy working positions. The effects of these conditions may not only be additive but also multiplicative in their effect on employee health. Tuomi et al. (1997) have demonstrated, in 11 year longitudinal study, that too large a physical load, too stressful a work environment, and a poorly organized work environment were the most important risk factors for poor work ability during ageing.

Stress is an important work component that can reduce work ability. Working conditions and work, which constantly stress the individual, result over time in stress syndromes, chronic conditions, and stress-related diseases, which in turn lower work ability. These stressors can cause chronic illnesses and can reduce functioning in everyday life, resulting in premature retirement and often premature death. Thus, for work ability to remain as high as possible it is necessary to ensure that both physical and mixed types of work adopt some of the characteristics of the mental types of work. This is important to ensure that both cognitive functioning and work ability, which can affect both physical and mental, functioning, remain high. Good work ability, during the last ten years at work, has been related to better health, better functional capacity, and a better quality of life 5 years after retirement (Tuomi et al. 2001). This is a very important finding for both the individual and the private and public entities that finance an individual after retirement. Better health, better functional capacity, and a better quality of life after retirement can result in a longer period of autonomous functioning and can reduce the need for support services from informal or formal health and social services providers.

In drawing conclusions and making generalizations, based on this study, it should be remembered that the sizes of the subgroups in the laboratory examinations were small. The small sample of the original population and the drop-outs may have biased our findings. It may be that only the fitter, healthier, and better-motivated subjects chose to participate in the study (Savinainen 2004). Furthermore, the study population represented workers in the Finnish municipal sector. This should not, however, be seen as a significant limitation when analyzing the relationship between WAI and cognitive functions, as in Finland, municipal employees encompass a wide range of occupations, including both, white- and blue-collar workers.

Low correlations between the WAI and MCF can at least be explained in part by the selection of tests and questions used. At the beginning of the follow-up period no prior research had been conducted into the relationship between WAI scores and cognitive functions. This means that the selection of the WAIS subtests in 1981 could not be based on earlier research data. However, the tests selected for our battery were proven to be valid through clinical practice of evaluations of psychological work ability conducted at the Finnish Institute of Occupational Health. In order to make the follow-up possible, there were no changes made in the test battery after the evaluation work, conducted in 1985 was completed.

Our study has other limitations besides what we have already discussed. The physical work group in the laboratory measurements was quite small. The sample adequately represented people working in the public sector, however, and it also included many different groups of workers doing similar jobs to those performed in the private sector. Future longitudinal studies on this topic should use subjects drawn from the private sector. It should be noted that during the course of this study, differences in work tasks, for given occupational category in the public and private sectors in Finland, greatly diminished.

In all longitudinal studies that start with a sample over aged 44 years, both illnesses and mortality will degrade the sample, reduce the size, and identify the healthier members of the cohort through survival. Participants in poor health at the start of a longitudinal study would be expected to have lower scores on the WAI index than those who were healthier. Moreover, those participants who survived to the end of the project would be expected to have lower WAI scores than they did at the beginning of the project. In the Finnish municipal sector, traditional job-related retirement ages still existed during the 1980's and 90's, the result of which is, that early exit possibilities from the workforce could have influenced the composition of our sample. The selected sample which can be followed-up is, of necessity, more homogeneous than the one we started with.

A more important restriction is that the one we started with, our present knowledge of cognitive functioning is much broader and deeper. In addition, measures for such broad areas as wisdom, expertise, creativity, and other important cognitive measures should be added in future research on the relationships between cognitive functioning and work ability. Also there should be included cognitive function measures which allow plenty of time for subjects to use when they try to find out solutions to the tasks presented to them. In addition, more tests assessing "crystallized intelligence" are needed to determine the importance of declines in work related cognitive function. In particular, there should be tests measuring executive functioning or the central executive (Baddeley 1996, 2000). This system is responsible for several functions, e.g. the storage and retrieval of information, controlling of action and planning, directing and switching of attention, and controlling of the information flow in the slave system (Baddeley 1996). Moreover, the ability to inhibit irrelevant information from entering working memory is thought to be one component of executive functioning (Baddeley et al. 1998) that would be important to evaluate in work settings requiring high degrees of vigilance for success performance. All these factors are necessary in nearly every type of work in a modern society. It should not be forgotten that an additional area of investigation should be an analysis of the relationship between emotional intelligence (Goleman, 1995) and work ability.

An important approach to this area of study would be to try to affect, by means of interventions, either cognitive functioning or work ability. We prefer an emphasis on the latter, especially for improving the working environment, organizational climate, supervisory practices and work content of persons engaged in mixed or physical types of work. We have already gathered a considerable amount of valid and important information on what the most important or critical work-related risk and resource factors are that affect work ability. Future efforts at intervention should attempt to decrease the risk factors and increase the resource factors, both in the working environment and with the work itself. It is also possible to have a positive effect on working individuals through training and guidance targeted to provide ways of decreasing individual risk factors and increasing individual resources. It is also essential to carry out much more comprehensive and thorough analyses of how different cognitive functions relate to work ability, using both cross sectional and longitudinal designs. Longitudinal studies should ideally have at least 3 to 4 assessments over a 15 year time frame and utilize a representative sample of workers from both the private and public sectors. A study, such as that by Kivimäki et al. (2002), thoroughly covered factors of importance to both work and the working environment and identified candidate factors for intervention that could improve an individual's cognitive functioning and work ability. Identifying factors with an impact, will contribute not only to the productivity of the enterprise or organization but also to that of the national economy.

When cognitive functioning and especially intelligence are analyzed in relation to work ability, it is important to emphasize the definitions and assumptions behind this analysis. We have used the analysis of cognitive processing going on and needed in problem solving which is necessary also in the working process. This is based on the following assumptions: 1) humans attend, gather and process information mainly through auditory and/or visual channels, often in combination; 2) this basic sensory processing is then analyzed by using the content of long-term memory wherein structural symbolism and/or abstraction of the current set to alternative cognitive sets are generated and elaborated; 3) these form the basis for the hypotheses to be tested for finding out solutions to a given problem; 4) when the solution evaluated to be the best one is determined, it is necessary to inhibit other competing solutions.

Intelligence is defined in this paper using the conclusions of a consensus panel of the American Psychological Association: "Individuals differ from another in their ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought" (Neisser, et al. 1996). This conceptualization of intelligence has been widely accepted and applies very well also to work life. However, it is necessary to differentiate the general factor (g) of intelligence, underlying performance on most, if not all, measures of higher cognitive functioning (Jensen, 1998) from the general intelligence which is a summation of standardized intelligence test scores. As noted by Jensen, the g-factor should be conceived as a "distillate of the common source of individual differences in all mental tests, completely stripped of their distinctive features of information content, skill, strategy, and the like" (Jensen, 1998, p. 74). The construct of g-factor relies upon the correlations among test scores. The simple sum of various test scores cannot be considered to form the optimal measure of general intelligence (g), but rather a measure of intelligence in general. Intelligence in general, which is the conceptualization used in this study, means g plus several more specific cognitive abilities and skills. Typical intelligence test scores like Wechsler's Adult Intelligence Test, comprise a complex mixture of those abilities and skills (Colom, et al. 2002). Although that kind of sum scores has high g-factor loadings, these scores only approximate g-factor.

Although the biological basis of cognitive functioning and intelligence has had a keen interest among researchers this area has been studied only recently, when research methods for this purpose have been sufficiently developed. Especially, the neuroimaging studies can give some answers when we try to understand how brain and behaviour are linked together through the expression of intelligence and reason. Jung and Haier (2007) have reviewed studies from functional (i.e. functional Magnetic Resonance Imaging, Positron Emission Tomography) and structural (i.e. Magnetic Resonance Spectroscopy, Diffusion Tensor Imaging, Voxel Based Mophometry) neuroimaging paradigms regarding the relations between physiological processes in brain and results of intelligence and reasoning tasks.

Earlier reviews concerning the biological correlates of intelligence and reasoning have analysed Positron Emission Tomography (PET) studies of cerebral glucose metabolic rate (Haier, 1993). Also the reaction time studies have been scrutinized assuming that the reaction time shows the speed and efficiency of brain functioning (Jensen, 1998). Especially, the importance of frontal lobe functioning has been studied in tasks representing a wide range of cognitive demands (Duncan, et al., 2000), including intelligence (Duncan, 2005). Besides, the frontal lobe functioning, the fronto-parietal integration in different cognitive tasks (Naghavi & Nyberg, 2005) as well as the cognitive processing efficiency and general intelligence (Chabris, 2006) has been reviewed.

Jung and Haier (2007) have developed the Parieto-Frontal Integration Theory, P-FIT. On the basis of reviewing 37 modern neuroimaging studies they conclude that "scores on many psychometrically-based measures of intellectual ability have robust correlates in brain structure and function" (p. 51). They also emphasize that intelligence research can now begin to detailly explore individual differences in the brain in relation to test scores. However, this research area is only in the beginning phase, because of many methodological problems. But it is important, that the brain functioning and brain structures activated in different intelligence and reasoning tasks, like chess, can and should also be analyzed in studying the relations between brain processes and work processes. Jung and Haier (2007, p. 53) propose that "by integrating spatio-temporal information (eg. simultaneous EEG-fMRI or cross platform fMRI-MEG experiments) one might expect to see a clarification of the relationships between performance and brain function/structure both within and outside of the network identified in the P-FIT". The most important conclusion on the basis of Jung's and Haier's (2007) study is that it shows strongly the correlates of some brain processes and brain areas to intelligence and reasoning tasks. The following step in relation to the topic of this paper would be the analysis of brain functions and areas influencing different kind of work tasks in real life settings. This will be possible in the very near future when the portable measurement devices to register brain processes while people are working have been developed.

It has been demonstrated in many studies that there are consistent correlates between the area functions and structures and cognitive functions including intelligent behaviour as assessed by intelligence and reasoning tests and tasks. However, this approach and its findings have also been criticized. Timo Järvilehto bases his criticism on the theory of the organism-environment system (Järvilehto, 1998a, 1998b, 1999, 2000). He argues that the mental activity is an activity or reorganization of the whole organism-environment system. This is not realized in the brain or in some other separate parts of the system, e.g. body as a whole, but by the organism-activity system as a whole. Mental activity can exist only if there are neural elements, although it cannot be reduced to their activity. Behaviour is included in mental activity if the latter is conceived as activity of the whole organism-environment system. On the basis of his theory there is no causal relation between mental activity and behaviour. Mental activity is related to the whole organism-environment system. Järvilehto states on the basis of his theory, that the appearance of mental activity as structured action and action results was possible only with the advent of neurons. This also explains why it is so seductive to regard the brain as the locus of mental activity.

Also on the epistemological basis it can be argued that it is only possible to find out correlates between biological brain processes and structures and different kind of behaviours. It is not possible to draw any kind of causal conclusions concerning the relations of brain processes to mental or physical behaviour.

The above described arguments are very important when trying to interpret the correlates between brain biological processes and mental and physical behaviour.

This report focused on only one scientifically interesting domain within the larger "Finn-Age" research programme that was carried out by the Finnish Institute of Occupational Health in collaboration with universities, pension insurance companies, and organization representatives from all sectors of the work environment. In another subproject within the programme, it has been noted that annual changes in psychological functioning are neither linear nor consistent, varying instead according to gender, the different cognitive variables assessed, and the different measurement times employed during the 16-year study period (Savinainen 2004).

7 CONCLUSIONS

The aim of this longitudinal study was to find out age-related changes in the Work Ability Index (WAI) and measured (MCF) as well as in self-rated cognitive functions (SCF) and their cross-sectional and longitudinal relations in physically, mixed physically and mentally, and mentally demanding work among municipal employees. The data on WAI were gathered in 1981-1997 and on cognitive functioning in 1985, 1992 and 1997. All measures had a satisfactory reliability.

The WAI decreased with ageing from 1981 to 1992 among men and women, and in all types of work. This decrease was, however, greater among women than among men. Also the WAIS scores (Similarities, Block Design, Digit Symbol, Digit Span, and Picture Completion) and the Bourdon-type Letter Cancellation test (NJEVD) lowered from 1985 to 1997 with the exception of the Digit Span test. These changes were non-significant showing the great stability of the cognitive functions at the end of working career as also other studies do. The WAIS scores were highest among those doing mentally demanding work. The important replicated finding was that the WAI began to decline in late middle-age, but the decrease of the WAIS and NJEDV scores started later and was slower among those who were still working and especially doing mentally demanding work. Especially the verbal skills and visual speed and accuracy were higher among those doing mentally demanding work than in other types of work groups. The largest drop in cognitive functioning was among those doing physically demanding work. The tests measuring more "crystallized" intelligence had very stable scores, but those measuring more "fluid" intelligence lowered more, however, not statistically significantly. All test scores' changes supported, although weakly, the generally found decline of cognitive functioning during ageing. Self-rated cognitive functions (reaction capacity, memory and sense of comprehension) partly improved during the 16-year follow-up and correlated higher with WAI than with the test scores.

All gender differences in cognitive functioning were not statistically significant in every assessment.

The findings showed a mutual interaction between the MCF scores and WAI. However, the cross-lagged correlations between MCF and WAI were very low, much lower than expected. However, the type of work moderated this relationship so, that the physically and mixed physically and mentally demanding works were detrimental for cognitive functioning and WAI. During the ageing process both cognitive functions and work ability affect each other, although on the basis of our study, only weakly. The very strong conclusion on the basis of these findings is that, to keep both cognitive functioning and the work ability high until the retirement age, the working environment and the work itself should include characteristics typical to mentally demanding work. Many of these characteristics are also those known generally to describe the works and work organizations which make possible for employees to develop him- or herself like clear and supportive leadership, a good organizational climate, possibility to learn and affect own work. These have also been the expectations of different employee-groups when they have been asked which factors keep them in work to late age and the lack of those characteristics drives them away from work already before the official retirement age.

YHTEENVETO

Tutkimuksen empiirisessä osassa etsittiin vastauksia seuraaviin tutkimuskysymyksiin:

1. Miten kognitiivinen toimintakyky ja työkykyindeksi muuttuvat ikääntymisen myötä? Eroavatko muutokset miesten ja naisten välillä ja erityyppisissä töissä? 2. Miten työkykyindeksi on yhteydessä mitattuihin ja koettuihin kognitiivisiin toimintoihin? Ovatko yhteydet samanlaiset miehillä ja naisilla ja erityyppisissä töissä? 3. Miten työkykyindeksin ja koetun psyykkisen toimintakyvyn yhteys muuttuu pitkällä aikavälillä? Onko tässä eroja sukupuolten ja töiden välillä?

Kunta-alan pitkittäistutkimukseen vuosina 1981-1997 osallistuneista (Tuomi ym., 1997) käytettiin tässä tutkimuksessa kahta tutkimusjoukkoa. Ensimmäinen koostui niistä, jotka osallistuivat laboratoriomittauksiin ja jotka olivat töissä 1981–1985 (n=68). Toisen tutkimusjoukon muodostivat ne, jotka vastasivat kaikkiin neljään kyselyyn (1981, 1985, 1992 ja 1997) ja jotka jatkoivat töissä vuoteen 1992 (n=717). Tätä kohorttia käytettiin itse arvioidun toimintakyvyn monimuuttuja-analyyseissa.

Työkykyä mitattiin Työterveyslaitoksessa kehitetyn Työkykyindeksin (TKI) avulla. Mittari muodostuu seitsemästä osiosta (Ilmarinen ym. 1997, Tuomi ym. 1998), joiden pisteet lasketaan yhteen. Se saa arvoja välillä 7-49.

Kognitiivinen toimintakyky määriteltiin Wechsler Adult Intelligence Scalen (WAIS) osatesteillä. Päättelykykyä mitattiin Samankaltaisuudet-testillä, avaruudellista hahmottamiskykyä Kuutiotehtävillä, visuo-motorista nopeutta Merkkikokeella, lyhytkestoista muistia Numerosarjoilla ja yleistä havainto- ja käsityskykyä Kuvien täydentämistehtävällä. Näköhavainnon nopeutta ja tarkkuutta mitattiin Bourdon-tyyppisellä kirjainviivaustestillä (NJEVD), jossa sattumanvaraisessa järjestyksessä olevista aakkosista tulee etsiä ja yliviivata viiden minuutin aikana tietyt viisi kirjainta. Osatestien pistearvot vakioitiin (keskiarvo 0, keskihajonta 1) ja kognitiivisen toimintakyvyn kokonaismittari (MCF) saatiin laskemalla osapisteet yhteen. Mittarin vaihteluväli oli -18 - 10. Mittareiden reliabiliteetit olivat 0,82 (1985), 0,85 (1992) ja 0,84 (1997).

Itse arvioidun kognitiivisen toimintakyvyn mittaus perustui kyselylomakkeen kysymyksiin erilaisista kognitiivisista toiminnoista, joissa vastaajaa pyydettiin arvioimaan itseään asteikolla heikko, melko heikko, tyydyttävä, hyvä tai erittäin hyvä. Tähän julkaisuun valittiin reaktiokyky, muisti ja käsityskyky, joista muodostettiin koetun kognitiivisen toimintakyvyn (SCF) mittari. Sen reliabiliteetti vaihteli välillä 0,82 (1985) ja 0,81 (1992 ja 1997). Asteikon vaihteluväli oli 2-15.

Työ luokiteltiin sen sisällön ja vaatimusten mukaan saksalaisella AET-menetelmällä (Ilmarinen ym. 1991) henkiseen työhön, ruumiilliseen työhön ja sekä henkiseen että ruumiilliseen työhön. (Tuomi ym. 1997). Sukupuoli ja ikä olivat mukana analyyseissä.

Seuranta-aikana 1981-1997 tapahtuneita muutoksia mitatussa ja koetussa toimintakyvyssä sekä työkyvyssä arvioitiin keskiarvojen avulla ja niiden tilastollinen merkitsevyys testattiin F-testeillä. Psykologisten testien, koetun toimintakyvyn ja työkykyindeksin yhteyksiä mitattiin Pearsonin korrelaatiokertoimella sekä polkumalleilla, ns. cross-lagged -korrelaatioilla (Amos-ohjelmisto). Vuoden 1985 koetun toimintakyvyn vaikutuksia työkykyyn vuonna 1992 sekä vastaavasti vuoden 1981 työkyvyn vaikutuksia kognitiiviseen toimintakykyyn vuonna 1997 analysoitiin yleisillä lineaarisilla malleilla. Sukupuoli, ikä ja työn perusmuoto olivat malleissa mukana.

Yleisesti WAIS -pistemäärät laskivat 1985–1997 numerosarjatestejä lukuun ottamatta. Tämä näkyi sekä miehillä että naisilla. Sukupuolten välillä oli eroja kuvien täydentämis- ja kuutiotesteissä, jotka sujuivat miehiltä paremmin sekä NJEVD-testissä, mikä puolestaan onnistui naisilta miehiä paremmin. Kokonaistoimintakyvyn mittaria tarkastellen miehillä oli naisia korkeampi kognitiivinen toimintakyky, mutta erot eivät olleet merkitseviä. Henkistä työtä tekevät suoriutuivat muita paremmin sekä kaikissa osatesteissä että kokonaistoimintakyvyltään. Voimakkainta lasku oli ruumiillisessa työssä.

Mitatusta toimintakyvystä poiketen koettu kognitiivinen toimintakyky kohentui seuranta-aikana 1985–1997. Tämä kehitys oli selvintä kokonaistoimintakyvyssä, sekä miehillä että naisilla samoin kuin kaikissa työn perusmuodon ryhmissä. Toimintakyvyn parantuminen oli voimakkainta ruumiillisen työn tekijöillä, joten ammattiryhmien väliset erot supistuivat seuranta-aikana.

Työkykyindeksi alentui 1981–1985 kaikissa ryhmissä. Alentuminen oli erityisen voimakasta naisten keskuudessa (37,9 - 33,2, $p<0{,}01$), mutta myös henkisen työn tekijöillä työkyky heikkeni merkitsevästi (40,3 - 36,4).

Kognitiivisten toimintojen ja työkykyindeksin korrelaatiot olivat kauttaaltaan vaatimattomia mutta kuitenkin positiivisia. Ryhmien välillä ilmeni kuitenkin joitakin voimakkaita eroja. Naisilla työkyvyn (1981) ja mitatun toimintakyvyn (1997) korrelaatio oli 0,54 mutta miehillä vain 0,05. Ruumiillisessa työssä vastaava korrelaatio oli 0,38, kun taas muissa työn perusmuodon ryhmissä lähellä nollaa.

Työkykyindeksi korreloi heikosti tai kohtalaisesti kaikkiin koetun kognitiivisen toimintakyvyn osioihin sekä miehillä että naisilla samoin kuin kaikissa työn perusmuodon ryhmissä. Koska korrelaatiot eivät kuvaa riippuvuuden suuntaa, yhteyksiä tarkasteltiin myös polkumallien avulla. Analyyseissa löytyi heikko, vaikkakin merkitsevä yhteys vuoden 1985 työkykyindeksin ja vuoden 1992 koetun toimintakyvyn välillä ($r=0{,}11$, $p<0{,}05$). Tämä tarkoittaa, että aiempi työkyvyn taso vaikuttaa kognitiivisiin toimintoihin.

Toimintakyvyn ja työkyvyn yhteyksiä tarkasteltiin kyselyaineistossa yleisillä lineaarisilla malleilla. Selitettävinä olivat sekä toimintakyky että työkykyindeksi, kumpikin omissa malleissaan. Kognitiivinen toimintakyky ennusti hyvää työkykyä seitsemän vuotta myöhemmin. Toisaalta taas havaittiin, että työkykyindeksi ennusti toimintakyvyn tasoa merkitsevästi jopa 16 vuoden kuluttua. Ruumiillisesti raskas työ heikensi sekä työkykyä että kognitiivista toimintakykyä.

REFERENCES

Ackerman, P., Rolfhus, E. 1999. The locus of adult intelligence: Knowledge, abilities, and nonability traits. Psychology and Aging 14, 314–330.

Alain, C., Woods, D. 1999. Age related changes in processing auditory stimuli during visual attention: Evidence for deficits in inhibitory control and sensory memory. Psychology and Aging 14, 507–519.

Allaire, J., Marsiske, M. 1999. Everyday cognition: Age and intellectual ability correlates. Psychology and Aging 14, 627–644.

Anderson, J. 1983. The architecture of cognition. Cambridge, MA: Harvard University Press.

Anstey, K., Hofer, S., Luszcz, M. 2003. Cross-sectional and longitudinal patterns of dedifferentiation in late-life cognitive and sensory function: The effects of age, ability, attrition, and occasion of measurement. Journal of Experimental Psychology: General 132, 470–487.

Anstey K., Smith G. 1999. Interrelationships among biological markers of aging, health, activity, acculturation, and cognitive performance in late adulthood. Psychology and Aging 14, 605–618.

Aromaa, A., Koskinen, S. 2004 (eds.). Health and functional capacity in Finland. Baseline Results of the Health 2000 Health Examination Survey. Helsinki: KTL- National Public Health Institute.

Baddeley, A. 1986. Working memory. Oxford: Oxford University Press.

Baddeley, A. 1996. Exploring the central executive. Quarterly Journal of Experimental Psychology 49A, 5–28.

Baddeley, A. 2000. The episodic buffer: a new component of working memory. Trends in Cognitive Sciences 4, 417–423.

Baddeley, A.D., Gathercole, S., Papagno, C. 1998. The phonological loop as a language learning device. Psychological Review 105, 158-173.

Baltes, P. 1993. The aging mind: Potential and limits. The Gerontologist 33, 580–594.

Baltes, P., Baltes, M. 1990. Psychological perspectives on successful aging: The model of selective optimization with compensation. In P. Baltes, M. Baltes (eds.), Successful aging: perspectives from the behavioral sciences. New York: Cambridge University Press, European Science Foundation, 1–34.

Baltes, P., Lindenberger. 1997. Emergence of a powerful connection between sensory and cognitive functions across adult life course: A new window to the study of cognitive aging. Psychology and Aging 12, 12–21.

Baltes, P., Smith, J. 1990. Toward a psychology of wisdom and its ontogenesis. In R. Sternberg (Ed.), Wisdom: Its nature, origins and development. New York: Cambridge University Press, 87–120.

Baltes, P., B., Smith, J., Staudinger, U. M. 1992. Wisdom and successful aging. Nebraska Symposium on Motivation 39, 123-167.

Baltes, P., Staudinger, U. 1993. The search for a psychology of wisdom. Current Directions in Psychological Science 2, 75–80.

Baltes, P., Staudinger, U. 2000. Wisdom: A metaheuristic to orchestrate mind and virtue towards excellence. American Psychologist 55, 122–135.

Baltes, P., Staudinger, U., Maercker, A., Smith, J. 1995. People nominated as wise: A comparative study of wisdom-related knowledge. Psychology of Aging 10, 155–166.

Bereiter, C. 2002. Education and mind in the knowledge. Hillsdale, NJ: Erlbaum.

Bereiter, C., Scardamalia, M. 1993. Surpassing ourselves - An inquiry into the nature and implications of expertise. Chicago and La Salle: Open Court.

Berg, C., Sternberg, R. 1985. A triarchic theory of intellectual development during adulthood. Developmental Review 5, 334–370.

Bialystok, E., Craik, F., Klein, R., Viswanathan. M. 2004. Bilingualism, aging, and cognitive control: Evidence from the Simon task. Psychology and Aging 19, 290–303.

Birren, J. 1965. Age changes in speed of behavior: Its central nature and physiological correlates. In A. Welford, J. Birren (eds.), Behavior, aging, and the nervous system. Springfield, IL: Charles C. Thomas, 191–216.

Birren, J., Fisher, L. 1990. The elements of wisdom: Overview and integration. In R. Sternberg (Ed.), Wisdom: Its nature, origins and development. New York: Cambridge University Press, 317–332.

Brébion, G., Smith, M., Ehrlich, M.-F. 1997. Working memory and aging: Deficit or strategy differences. Aging, Neuropsychology, and Cognition 4, 58-73.

Brown, S. 1996. Control of simple arm movements in the elderly. In A. Fernandez, N. Teasdale (eds.),, Changes in sensory motor behavior in aging. Vol. 114. North Holland: Elsevier Science BV.

Bäckman, L., Small, B., Wahlin, Å. 2001. Aging and memory. Cognitive and biological perspectives. In J. Birren, K., Schaie (eds.), Handbook of the psychology of aging, 5th edition. San Diego, CA: Academic Press, 349–377.

Cattell, R. B. 1971. Abilities: Their structure, growth, and action. Boston, MA: Houghton Mifflin.

Cerella, J. 1985. Information processing rates in the elderly. Psychological Bulletin 98, 67–83.

Chan, S. 1990. Cognitive processes in architectural design problem solving. Design Studies 11, 60–79.

Charness, N. 2000. Can acquired knowledge compensate for age-related declines in cognitive efficiency. In S. Qualls, N. Abeles (eds.), Psychology and the aging revolution. How we adapt to longer life. Washington, DC: American Psychological Association, 99–117.

Chastain, R., Joe, G. 1987. Multidimensional relations between intellectual abilities and demographic variables. Journal of Educational Psychology 79, 323–325.

Costa, G., Goedhard, W. J. A., Ilmarinen, J. 2005 (eds.), Assessment and promotion of work ability, health and well-being of ageing workers. International Congress Series 1280. The Netherlands: Elsevier.

Cox, T., Griffiths, A., Rial-Gonzalez, E. 2000. Research on work-related stress. Luxembourg: Office for Official Publications of the European Communities, European Agency for Safety & Health at Work.

Elder, G. H. 1974. Children of the Great Depression. Chicago: University of Chicago Press.

Elo, A-L., Mattila, P., Kylä-Setälä, E., Kuosma, E. 2004. Evaluation of an organizational workplace health promotion program in municipal public works. Työ ja ihminen, Tutkimusraportti 26. Työterveyslaitos, Helsinki (in Finnish).

Era, P. 1987. Sensory, psychomotor, and motor functions in men of different ages. Scandinavian Journal of Social Medicine, Suppl. 39.

Eraut, M. 1994. Developing professional knowledge and competence. London: The Falmer Press.

Ericsson, K., Charness, N. 1994. Expert performance; Its structure and acquisition. American Psychologist 49, 725–747.

Ericsson, K., Kintsch, W. 1995. Long-term working memory. Psychological Review 102, 211–245.

Ericsson, K., Krampe, R., Tesch-Römer, C. 1993. The role of deliberate practice in the acquisition of expert performance. Psychological Review 100, 363–406.

Ericsson, K., Lehman, A. 1996. Expert and exceptional performance: Evidence on maximal adaptation to task constraints. Annual Review of Psychology 47, 273–305.

Eskelinen, L., Kohvakka, A., Merisalo, T., Hurri, H., Wägar, G. 1991. Relationship between the self assessment and clinical assessment of health status and work ability. Scandinavian Journal of Work Environment Health 17 (Suppl. 1), 40-7.

European Commission. Employment in Europe 2003. Recent trends and prospects. Belgium: European Commission.

Eteläpelto, A. 1998. The development of expertise in information systems design. Jyväskylä Studies in Education, Psychology and Social Research 146. Jyväskylä: Jyväskylä University Printing House.

Falkenstein, M., Hoormann, J., Hohnsbein, J. 2002. Inhibition related ERP components: Variation with modality, age, and time on task. Journal of Psychophysiology 16, 167–175.

Feather, N. T. 1990. The psychological impact of unemployment. New York: Springer.

Feltowitch, P., Ford, K., Hoffman, R. 1997 (eds.). Expertise in context: Human and machine. Menlo Park, CA: AAAI Press/ The MIT Press.

Ferrie, J. E. 2000. Factors underlying the effect of organizational downsizing on health of employees: Longitudinal cohort study. British Medical Journal 320, 971–975.

Fischer, K., Yan, Z., Stewart, J. 2003. Adult cognitive development: Dynamics in the developmental web. In J. Valsiner, K. Connolly (eds.), Handbook of developmental psychology. London: Sage, 491–516.

Fozard, J. 2000. Sensory and cognitive changes with age. In K. Schaie, M. Pietrucha (eds.), Mobility and transportation in the elderly. New York: Springer, 1–44.

Fozard, J., Gordon-Salant, S. 2001. Changes in vision and hearing with aging. In J. Birren, K. Schaie (eds.), Handbook of the psychology of aging, 5th edition. San Diego, CA: Academic Press, 241–266.

Fozard, J., Heikkinen, E. 1998. Maintaining movement ability in old age. In J. Graafmans, V. Taipale, N. Charness (eds.), Gerontechnology: A sustainable investment in the future. Amsterdam: IOS Press, 48–61.

Fromholt, P., Berg, S. 1997. Self-reported memory and cognitive performance among 75-year-old people from three Nordic cities. In E. Heikkinen, S. Berg, M. Schroll, B. Steen & A. Viidik (eds.), Functional status, health and aging: The NORA study. Facts, Research and Intervention in Geriatrics, 55-65. Paris: Serdi.

Goleman, D. 1995. Emotional intelligence. New York: Bantom.

Gould, R., Ilmarinen, J., Järvisalo, J., Koskinen, S. 2006. Työkyvyn uudet ulottuvuudet (New dimension of work ability), Kansanterveyslaitos, Eläketurvakeskus, Kansaneläkelaitos ja Työterveyslaitos, Helsinki.

Gruber, H. 1994. Expertise: Modelle und empirische Untersuchungen. Beiträge zur psychologischen Forschung, Band 34. Opladen: Westdeutscher Verlag.

Hasher, L., Zacks, R. 1988. Working memory, comprehension and aging: A review and a new view. In G. Bowker (Ed.), The Psychology of learning and motivation (Vol. 22). San Diego, CA: Academic Press, 193–225.

Henry, J., MacLeod, M., Phillips, L., Crawford, J. 2004. A meta-analytic review of prospective memory and aging. Psychology and Aging 19, 27–39.

Herno, H-T., Feldt, T., Ruoppila, I., Rasku, A. 2000. Changes in managers' sense of coherence and well-being during the years 1996-1999. Reports from the Department of Psychology, University of Jyväskylä, 345. Jyväskylä: Jyväskylä University Press (in Finnish with English Summary).

Hertzog, C., Dixon, R., Hultsch, D., MacDonald, S. 2003. Latent change models of adult cognition: Are changes in processing speed and working memory associated with changes in episodic memory? Psychology and Aging 18, 755–769.

Holyoak, K. 1991. Symbolic connectionism: Toward third-generation theories of expertise. In K. Ericsson, J. Smith (eds.), Toward a general theory of expertise - Prospect and limits. New York: Cambridge University Press, 310–335.

Horn, J., Cattell, R. 1967. Age differences in fluid and crystallized intelligence. Acta Psychologica 26, 107–129.

Hunter, J., Schmidt, F. 1996. Intelligence and job performance: Economic and social implications. Psychology, Public Policy, and Law 2, 447–472.

Huuhtanen, P., Nygård, C-H., Tuomi, K,. Martikainen, R. 1997. Changes in stress symptoms and their relationship to changes at work in 1981-1992 among elderly workers in municipal occupations. Scandinavian Journal of Work Environment Health 23 (Suppl. 1), 36-48.

Ilmarinen, J. 1991. (Ed.) The aging worker.Scandinavian Journal of Work Environment and Health 17(suppl 1).

Ilmarinen J. 1993. (Ed.) Aging and Work. International Scientific Symposium on Aging and Work, May 1992, Haikko, Finland. Proceedings 4. Finnish Institute of Occupational Health, Helsinki.

Ilmarinen, J. 1999. Ageing workers in the European Union - Status and promotion of work ability, employability and employment. Finnish Institute of Occupational Health. Helsinki: Ministry of Social Affairs and Health, Ministry of Labour.

Ilmarinen, J. 2002. Physical requirements associated with the work of ageing workers in the European Union. Experimental Aging Research 28, 7-23.

Ilmarinen, J., Louhevaara, V. 1999. (eds.) FinnAge - Respect for the Ageing: action programme to promote health, work ability and well-being of ageing workers in 1990-1996. People and Work. Research reports 26. Helsinki: Finnish Institute of Occupational Health.

Ilmarinen, J., Suurnäkki, T., Nygård, C-H., Landau, K. 1991. Classification of municipal occupations. Scandinavian Journal of Work Environment Health 17 (Suppl 1), 12-29.

Ilmarinen, J., Tuomi, K. 2004. Past, present and future of work ability. In J.Ilmarinen, S.Lehtinen (eds.), People and Work Research Reports 65, 1-25.

Ilmarinen, J., Tuomi, K., Eskelinen, L., Nygård, C-H., Huuhtanen, P., Klockars, M. 1991. Summary and recommendations of a project involving cross-sectional and follow-up studies on the ageing worker in Finnish municipal occupations (1981-1985). Scandinavian Journal of Work Environment Health 17 (Suppl 1), 135-41.

Ilmarinen, J., Tuomi, K., Klockars, M. 1997. Changes in the work ability of active employees over an 11-year period. Scandinavian Journal of Work Environment Health 23 (Suppl. 1), 49-57.

Ilmarinen, J., Tuomi, K., Seitsamo, J. 2005. New dimension of work ability. In G.Gosta, W.J A. Goedhard, J.Ilmarinen (eds.), Assessment and promotion of work ability, health and well-being of ageing workers. International Congress Series 1280. The Netherlands, Elsevier, 3-7.

Jahoda, M. 1982. Employment and unemployment: A social psychological analysis. Cambridge: Cambridge University Press.

Jahoda, M. 1988. Economic recession and mental health: Some conceptual issues. Journal of Social Issues 44, 13–24.

Jenkins, L., Myerson, J., Joerding, J., Hale, S. 2000. Converging evidence that visuospatial cognition is more age sensitive than verbal cognition. Psychology and Aging 15, 157–175.

Kalimo, R., Lindström, K., Smith, M. J. 1997. Psychosocial approach in occupational health. In G. Salvendry (Ed.), Handbook of human factors and ergonomics. New York: John Wiley & Sons, 1059–1084.

Ketcham, C., Stelmach, G. 2001. Age-related declines in motor control. In J. Birren, K. Schaie (eds.), Handbook of the psychology of aging. 5th edition. San Diego, CA: Academic Press, 313–348.

Kivimäki, M., Vahtera, J., Virtanen, M., Elovainio, M., Pentti, J., Ferrie, J. E. 2003. Temporary employment risk of overall and cause-specific mortality. American Journal of Epidemiology 158, 663-668.

Lamar, M., Zonderman, A., Resnick, S. 2002. Contribution of specific cognitive processes to executive functioning in an aging population. Neuropsychology 16, 156-162.

Laukkanen, P., Leinonen, R., Heikkinen, E. 1999. Health status among Finnish persons born 1904–23 in an eight-year follow-up study. In T. Suutama, I. Ruoppila, P. Laukkanen (eds.), Changes in functional abilities among elderly people. Findings from an eight-year follow-up study by the Evergreen project. The Social Insurance Institution, Finland, Studies in Social Security and Health 42. Helsinki: Hakapaino Oy, 133-170 (in Finnish with English summary).

Laursen, P. 1997. The impact of aging on cognitive functions. An 11-year follow-up study of four age cohorts. Acta Neurologica Scandinavica 96, Suppl. 172.

Light, L. 2000. Memory changes in adulthood. In S. Qualls, N. Abeles (eds.), Psychology and the aging revolution. How we adapt to longer life. Washington, DC: American Psychological Association, 73–97.

Lindenberger, U., Reischies, F. 1999. Limits and potentials of intellectual functioning in old age. In P. Baltes, K. Mayer (eds.), The Berlin Aging Study: Aging from 70 to 100. Cambridge: Cambridge University Press, 329–359.

Louhevaara, V., Klemola, S. 2003. Changes in the work ability index of aging workers related to participation in activities for promoting health and work ability: a 3 year program. In M. Kumashiro (ed.), Aging and Work. London and New York: Taylor and Francis, 185-192.

Lubart, T. 1994. Creativity. In R. Sternberg (Ed.), Thinking and problem solving. New York: Academic Press, 289–332.

Lubart, T. 1999. Creativity across cultures. In R. Sternberg (Ed.), Handbook of creativity. New York: Cambridge University Press, 339–350.

Ly, D., Lockhardt, D., Lerner, R., Schultz, P. 2000. Mitotic misregulation and human aging. Science 287, 2486-2492.

Madden, D. 2001. Speed and timing of behavioral processes. In J. Birren, K. Schaie (eds.), Handbook of the psychology of aging, 5th edition. San Diego, CA: Academic Press: 288–312.

Maurer, T., Weiss, E., Barbeite, F. 2003. A model of involvement in work related learning and development activity: The effects of individual, situational, motivational, and age variables. Journal of Applied Psychology 88, 707–724.

Miller, I. J. Jr. 1988. Human taste bud density across adult age groups. Journal of Gerontology: Biological Sciences 43, B26-B30.

Mintzer, J., Burns, A. 2002. Anticholinergic side-effects of drugs in elderly people. Journal of the Royal Society of Medicine 93, 457–462.

Newell, A. 1990. Unified theories of cognition. Cambridge: Harward University Press.

Newell, A., Simon, H. 1972. Human problem solving. Englewood Cliffs, NJ: Prentice-Hall.

NIOSH 2002. The Changing Organization of Work and the Safety and Health of Working People. Knowledge Gaps and Research Directions. US Department of Health and Human Services. CDC, NIOSH (April).

Nygård, C-H., Eskelinen, L., Suvanto, S., Tuomi, K., Ilmarinen, J. 1991. Associations between functional capacity and work ability among elderly municipal amployees. Scandinavian Journal of Work Environment Health 17 (Suppl. 1), 122-127.

Nygård, C-H., Huuhtanen, P., Tuomi, K., Martikainen, R. 1997. Perceived work changes between 1981 and 1992 among aging workers in Finland. Scandinavian Journal of Work Environment Health 23 (Suppl. 1), 12-19.

Nygård, C-H., Suurnäkki, T., Ilmarinen, J. 1999. Job demands of ageing employees over 12-years period. In J. Ilmarinen and V. Louhevaara (eds.), FinnAge-Respect for the aging: Action programme to promote health, work ability and well-being of ageing workers in 1990-96. People and Work, Research Reports 26. Helsinki: Finnish Institute of Occupational Health.

Owens, D., Tyrrell, A. 1999. Effects of luminance, blur, and age on nighttime visual guidance: A test of the selective degradation hypothesis. Journal of Experimental Psychology 5, 1–14.

Owsley, C., McGwin, Jr., G, Ball, K. 1998. Vision impairment, eye disease, and injurious motor vehicle crashes in the elderly. Ophthalmic Epidemiology 5, 101–113.

Parasuraman, R. 1998. The attentive brain: Issues and prospects. In R. Parasuraman (Ed.), The attentive brain, Cambridge, MA: MIT Press, 3–15.

Perryman, K., Fitten, J. 1996. Effects of normal aging on the performance of motor vehicle operational skills. Journal of Geriatric Psychiatry and Neurology 9, 136–141.

Quillian-Wolever, R. E., Wolever, M. E. 2002. Stress management at work. In J.C. Quick, L.E. Tetric (eds.), Handbook of occupational health psychology. Washington, DC: American Psychological Association, 355–378.

Rabbitt, P., Anderson, M., Davis, H., Shilling, V. 2003. Cognitive processes in ageing. In J. Valsiner, K. Connolly (eds.), Handbook of developmental psychology. London: Sage, 560–583.

Rambow, R., Bromme, R. 1995. Implicit psychological concepts in architects' knowledge - How large is a large room? Learning and Instruction 5, 337–356.

Rantanen, J. 2002. Work and working conditions in globalized economies. People and Work, Research Reports 49. Helsinki: Finnish Institute of Occupational Health, 28-40.

Ritchie, K., Lovestone, S. 2002. The dementias. Lancet 360, 1759–1766.

Roberts, A., Tracy, C. S. 1998. Health and productivity of older workers. Scandinavian Journal of Work Environment Health 24, 85–97.

Rogers, W., Fisk, A. 2001. Understanding the role of attention in cognitive aging research. In J. Birren, K. Schaie (eds.), Handbook of the psychology of aging, 5th edition. San Diego, CA: Academic Press, 267–287.

Ruoppila, I., Suutama, T. 1997a. Cognitive functioning of 75- and 80-year-old people and changes during a 5-year follow-up. Scandinavian Journal of Social Medicine, Suppl. 53, 44–65.

Ruoppila, I., Suutama, T. 1997b. Cognitive functioning of 75-year-old people in relation to mood, self-rated health and metamemory: A study in three Nordic localities. In E. Heikkinen, S. Berg, M. Schroll, B. Steen, A. Viidik (eds.), Functional status, health and aging: The NORA study. Facts, Research and Intervention in Geriatrics, Paris: Serdi, 79-92.

Ruoppila, I. & Suutama, T. 2003. Changes in cognitive performance among Finnish older persons ageing from 75 to 85. Revista Espanola de Geriatria y Gerontologia 38, Suppl. 1, 223.

Rutenfranz, J. 1981. Arbeitsmedizinische Aspekte des Stressproblems. In J.R.Nitsh (Ed.), Theorien, Untersuchungen, Massnahmen. Bern-Stuttgart-Wien: Verlag Hans Huber, 379-90.

Saariluoma, P. 1995. Chess players' thinking. A cognitive psychological approach. London and New York: Routledge.

Salthouse, T. 1985. Speed of behavior and its implications for cognition. In J. Birren, K. Schaie (eds.), Handbook of the psychology of aging, 2nd. edition. New York: Van Nostrand Reinhold, 400–426.

Salthouse, T. 1988. Cognitive aspects of motor functioning. Annals of the New York Academy of Science 515, 33–41.

Salthouse, T. 1991. Theoretical perspectives on cognitive aging. Hillsdale, NJ: Erlbaum.

Salthouse, T. 1994. The nature of the influence of speed on adult age differences in cognition. Developmental Psychology 30, 240–259.

Salthouse, T. 1997. Implications of adult age differences in cognition for work performance. In Å. Kilbom et al. (eds.), Work after 45? Volume I. Arbete och hälsa. Solna: Arbetslivsinstitut, 15-28.

Salthouse, T. 1998. Cognitive and information-processing perspectives on aging. In I. Nordhus, G. VandenBos, S. Berg, P. Framholt (eds.), Clinical geropsychology. Washington, DC: American Psychological Association, 49–59.

Salthouse, T. 1999. Theories of cognition. In V. Bengtson, K. Schaie (eds.), Handbook of theories of aging. New York: Springer, 196–208.

Salthouse, T., Babcock, R. 1991. Decomposing adult age differences in working memory. Developmental Psychology 27, 763-776.

Savinainen, M. 2004. Physical capacity and workload among ageing workers. Acta Universitatis Tamperensis 1025. Tampere: Tampere University Press.

Schacter, D. 1987. Implicit memory: History and current status. Journal of Experimental Psychology: Learning, Memory, and Cognition 13, 477–494.

Schaie, K. 1988. Internal validity threats in studies of adult cognitive development. In M. Howe, C. Brainard (eds.), Cognitive development in adulthood: Progress in cognitive development research. New York: Springer-Verlag, 241–272.

Schaie, K. 1996. Intellectual development in adulthood: The Seattle Longitudinal Study. New York: Cambridge University Press.

Schaie, K. 2000. The impact of longitudinal studies on understanding development from young adulthood to old age. International Journal of Behavioral Development 24, 267–275.

Schaie, K. 2001. Emotional intelligence: Psychometric status and developmental characteristics - comments on Roberts, Zeidner, and Matthews. Emotion 1, 243-248.

Schaie, K. 2005. Developmental influences on adult intelligence: The Seattle longitudinal Study. New York: Oxford University Press.

Schaie, K. W. & Caskie, G. I. L. 2005. Methodological issues in aging research. In D. M. Teti (Ed.), Handbook of research in developmental psychology. Cambridge, UK: Backwell, 21-69.

Schaie, K., Hofer, S. 2001. Longitudinal studies in aging research. In J. Birren, K. Schaie (eds.), Handbook of the psychology of aging, 5th edition. San Diego, CA: Academic Press, 53–77.

Schaie, K., Willis, S. 1996. Adult development and aging, 4th edition. New York: HarperCollins.

Shah, P., Miayke, A. 1996. The separability of working memory resources for spatial thinking and language processing: An individual differences approach. Journal of Experimental Psychology: General 125, 4–27.

Simonton, D. 1999. Creativity from a historiometric perspective. In R. Sternberg (Ed.), Handbook of creativity. New York: Cambridge University Press, 116–133.

Sliwinski, M., Buschke, H. 1999. Cross sectional and longitudinal relationships among age, cognition, and processing speed. Psychology and Aging 14, 18–33.

Smith, J., Baltes, P. 1990. Wisdom-related knowledge: Age/cohort differences in responses to life planning problems. Developmental Psychology 26, 494–505.

Smith, J., Staudinger, U., Baltes, P. 1994. Occupational settings facilitating wisdom-related knowledge: The sample case of clinical psychologists. Journal of Consulting and Clinical Psychology 62, 989–999.

Smith, M. J., Karsh, B-T., Carayon, P., Conway, F. T. 2002. Controlling occupational safety and health hazards. In J.C. Quick, E. Tetrick (eds.), Handbook of occupational health psychology. Washington DC: American Psychological Association, 35-68.

Sonnentag, S. 1995. Excellent software professional: Experience, work activities, and perception by peers. Behavior & Information Technology 14, 289–299.

Spitzer, M. E. 1988. Taste acuity in institutionalized and noninstitutionalized elderly men. Journal of Gerontology: Psychological Sciences 43, P71–P74.

Staudinger, U. 1999. Older and wiser? Integrating results on the relationship between age and wisdom-related performance. International Journal of Behavioral Development 23, 641–664.

Staudinger, U., Lopez, D., Baltes, P. 1997. The psychometric location of wisdom-related performance: intelligence, personality and more? Personnel and Social Psychology 23, 1200–1214.

Staudinger, U., Werner, I. 2003. Wisdom: Its social nature and lifespan development. In J. Valsiner, K. Connolly (eds.), Handbook of developmental psychology. London: Sage, 584–600.

Sternberg, R. 1990. Wisdom and its relations to intelligence and creativity. In R. Sternberg (Ed.), Wisdom: Its nature, origins, and development. New York: Cambridge University Press, 142–159.

Sternberg, R. 1998. A balance theory of wisdom. Review of General Psychology 2, 347–365.

Sternberg, R., Lubart, T. 1995. Defying the crowd: Cultivating creativity in a culture of conformity. New York: Free Press.

Sternberg, R., Lubart, T. 2001. Wisdom and creativity. In J. Birren, K. Schaie (eds.), Handbook of psychology of aging, 5th edition. San Diego, CA: Academic Press, 500–522.

Stevens, J. C., Cain, W. S. 1987. Old-age deficits in the sense of smell as gauged by thresholds, magnitude matching, and odor identification. Psychology and Aging 2, 36–42.

Suvanto, S., Huuhtanen, P., Nygård, C-H., Ilmarinen, J. 1991. Performance efficiency and its changes among aging municipal employees. Scandinavian Journal Work Environment Health 17 (Suppl. 1), 118-21.

Swanson, H. 1999. What develops in working memory? A life course perspective. Developmental Psychology 35, 986–1000.

Tulving, E. 1983. Elements of episodic memory. Oxford: Oxford University Press.

Tuomi, K. 1997. (Ed.) Eleven-year follow-up of aging workers. Scandinavian Journal Work Environment and Health 23, (1).

Tuomi, K., Huuhtanen P., Nykyri E., Ilmarinen, J. 2001. Promotion of work ability, the quality of work and retirement. Occupational Medicine 51, 318-324.

Tuomi, K., Ilmarinen, J., Eskelinen, L., Järvinen, E., Toikkanen, J., Klockars, M. 1991. Prevalence and incidence rates of diseases and work ability in different work categories of municipal occupations. Scandinavian Journal Work Environment Health 17, 67-74.

Tuomi, K., Ilmarinen, J., Jahkola A., Katajarinne, L., Tulkki, A. 1998. Work Ability Index. Helsinki: Finnish Institute of Occupational Health.

Tuomi, K., Ilmarinen, J., Klockars, M., Nygård, C-H., Seitsamo, J., Huuhtanen, P., Martikainen, R., Aalto, L. 1997. Finnish research project on aging workers in 1981-1992. Scandinavian Journal Work Environment Health 23 (Suppl. 1), 7-11.

Tuomi, K., Wägar, G., Eskelinen, L., Järvinen, E., Huuhtanen, P., Suurnäkki, T., Fahlström, P., Aalto, L., Ilmarinen, J. 1985. Health, work capacity, and work conditions in municipal occupations (In Finnish with an English abstract). Työterveyslaitoksen tutkimuksia 3(2), 95-132.

Uotinen, V. 1998. Age identification: A comparison between Finnish and North-American cultures. International Journal of Aging and Human Development 46, 109–124.

Uotinen, V., Suutama, T., Ruoppila, I. 2003. Age identification in the framework of successful aging: A study of older Finnish people. International Journal of Aging and Human Development 56, 171–193.

Vaillant, G. E. 1993. The wisdom of the ego. Cambridge, MA: Harvard University Press.

Verhaeghen, P., Salthouse, T. 1997. Meta analyses of age-cognition relations in adulthood: Estimates of linear and nonlinear age effects and structural models. Psychological Bulletin 122, 231–249.

Waltz, D., Elam, J., Curtis, B. 1993. Inside a software design team: Knowledge acquisition, sharing, and integration. Communications of the ACM 36, 63–77.

Wecker, N., Kramer, J., Wisniewski, A., Delis, D., Kaplan, E. 2000. Age effects on executive ability. Neuropsychology 14, 409–414.

Willis, S., Schaie, K. 1994. Cognitive training in the normal elderly. In F. Forette, Y. Christen, F. Boller (eds.), Plasticité cérébrale et stimulation cognitive. Paris: Fondation National de Gérontologie, 91–113.

Zelinski, E., Crimmins, E., Reynolds, S., Seeman, T. 1998. Do medical conditions affect cognition in older adults? Health Psychology 17, 504–572.

APPENDIX 1

FINNISH INSTITUTE OF OCCUPATIONAL HEALTH

WORK ABILITY INDEX QUESTIONNAIRE

On this form, please give your opinion of your work ability and the factors affecting it. Using your responses, occupational health professionals will collaborate with you to determine both your need for supportive action and any need to improve your working conditions. Please fill out the form carefully and answer every question. Answer the questions by circling the number of the alternative you feel best reflects your opinion or by writing your response in the space given. All of the information you give will be kept strictly confidential, and it will be used only for occupational health care purposes.

Your responses will be kept for 10 years by occupational health professionals. They will use the information to promote your well-being in the workplace. Your filling out the questionnaire is, of course, voluntary.

Date ______ / ________________

Surname and first names ____

Date of birth _______ / __________________

BACKGROUND

SEX
Female.. 1
Male... 2

AGE ________ years

MARITAL STATUS
Unmarried.. 1
Married... 2
Unmarried but co-habiting............... 3
Separated... 4
Divorced... 5
Widow/widower..................................... 6

BASIC EDUCATION
Elementary school.................................. 1
Comprehensive school........................... 3
Intermediate school.................................. 4
Secondary school.................................. 5

VOCATIONAL/PROFESSIONAL EDUCATION
Vocational course for the unemployed
(at least 4 months)....................................1
Other vocational course
(at least 4 months).................................... 2
Vocational school.................................... 3
Vocational institute/college....................4
University..5
Other training, what? 6

OCCUPATION

WORK TASK

INDUSTRIAL BRANCH OF EMPLOYMENT
(To be filled out by occupational health personnel)

WORKPLACE

DEPARTMENT

ARE THE DEMANDS OF YOUR WORK PRIMARILY....?
Mental 1
Physical 2
Both mental and physical 3

WORK ABILITY INDEX

1. Current work ability compared with lifetime best

Assume that your work ability at its best has a value of 10 points. How many points would you give your current work ability?
(0 means that you cannot currently work at all)

0	1	2	3	4	5	6	7	8	9	10
completely unable to work									work ability at its best	

2. Work ability with relation to demands of the job

How do you rate your current work ability with respect to the **physical** demands of your work?

very good	5
farily good...	4
moderate..	3
rather poor...	2
very poor..	1

How do you rate your current work ability with respect to the **mental** demands of your work?

very good...	5
fairly good..	4
moderate...	3
rather poor..	2
very poor..	1

3. Number of current diseases diagnosed by a physician

In the following list, mark your diseases or injuries. Also indicate **whether a physician has diagnosed** or treated these diseases. Thus, for each disease you can circle 2, 1, or no alternatives.

	yes own opinion	physician's diagnosis
Injury from accident		
01 back	2	1
02 arm/hand...	2	1
03 leg/foot..	2	1
04 other part of body, where and what kind of injury?.................	2	1

____

	yes own opinion	physician's diagnosis
Musculoskeletal disease		
05 disorder of the upper back or cervical spine, repeated instances of pain................	2	1
06 disorder of the lower back, repeated instances of pain................	2	1
07 (sciatica) pain radiating from the back down the leg............................	2	1
08 musculoskeletal disorder affecting the limbs (hands, feet), repeated instances of pain................	2	1
09 rheumatoid arthritis.............................	2	1
10 other musculoskeletal disorder, what?...	2	1
Cardiovascular disease		
11 hypertension (high blood pressure)......................	2	1
12 coronary heart disease, chest pains during exercise (angina pectoris)..............................	2	1
13 coronary thrombosis, myocardial infarction.........................	2	1
14 cardiac insufficiency..........................	2	1
15 other cardiovascular disease, what?...	2	1
Respiratory disease		
16 repeated infections of the respiratory tract (including tonsillitis, acute sinusitis, acute bronchitis).....	2	1
17 chronic bronchitis...............................	2	1
18 chronic sinusitis.................................	2	1
19 bronchial asthma...............................	2	1
20 emphysema.......................................	2	1
21 pulmonary tuberculosis...................	2	1
22 other respiratory disease, what?..	2	1
Mental disorder		
23 mental disease or severe mental health problem (for example, severe depression, mental disturbance)..	2	1
24 slight mental disorder or problem (for example, slight depression, tension, anxiety, insomnia).............	2	1

	yes own opinion	physician's diagnosis
Neurological and sensory disease		
25 problems or injury to hearing...........	2	1

26 visual disease or injury (other than refractive error)................	2	1
27 neurological disease (for example, stroke, neuralgia, migraine, epilepsy)............................	2	1
28 other neurological or sensory disease, what?....................................	2	1
Digestive disease		
29 gall stones or disease.......................	2	1
30 liver or pancreatic disease...............	2	1
31 gastric or duodenal ulcer....................	2	1
32 gastritis or duodenal irritation...........	2	1
33 colonic irritation, colitis......................	2	1
34 other digestive disease, what?..	2	1
Genitourinary disease		
35 urinary tract infection.........................	2	1
36 kidney disease.................................	2	1
37 genital disease, (for example, fallopian tube infection in women or prostatic infection in men)...........	2	1
38 other genitourinary disease, what?..	2	1
Skin disease		
39 allergic rash/excema.......................	2	1
40 other rash, what?.............................	2	1
41 other skin disease, what?..............	2	1
Tumor		
42 benign tumor..................................	2	1
43 malignant tumor (cancer), where?..	2	1

	yes own opinion	physician's diagnosis
Endocrine and metabolic diseases		
44 obesity	2	1
45 diabetes	2	1
46 goiter or other thyroid disease	2	1
47 other endocrine or metabolic disease, what?	2	1
Blood diseases		
48 anemia	2	1
49 other blood disorder, what?	2	1
Birth defects		
50 birth defect, what?	2	1
Other disorder or disease		
51 what?	2	1

4. Estimated work impairment due to disease

Is your illness or injury a hindrance to your current job?
Circle more than one alternative if needed.

It is no hindrance/ I have no diseases	6
I am able to do my job, but it causes some symptoms	5
I must **sometimes** slow down my work pace or change my work methods	4
I must **often** slow down my work pace or change my work methods	3
Because of my disease, I feel I am able to do only part-time work	2
In my opinion, I am entirely unable to work	1

5. Sick leave over the past year (12 months)

How many **whole days** have you been off work because of a health problem (disease, health care or for examination) during the past year (12 months)?

none	5
max. 9 days	4
10–24 days	3
25–99 days	2
100–365 days	1

6. Own prognosis of work ability two years from now

Do you believe that, from the standpoint of your health, you will be able to do your current job **two years from now**?

unlikely	1
not certain	4
relatively certain	7

7. Mental resources

Have you recently been able to enjoy your regular daily activities?

often	4
fairly often	3
sometimes	2
seldom	1
never	0

Have you recently been active and alert?

always	4
fairly often	3
sometimes	2
seldom	1
never	0

Have you recently felt full of hope for the future?

continuously	4
fairly often	3
sometimes	2
seldom	1
never	0

Informed consent (promotion and maintenance of work ability in general)

Do you consent to permit a summary of the preceding data and the score of your work ability index to be included in your health records?

yes .... ☐
no .... ☐

____

signature