Aging and Human Factors

Proceedings of the Europe Chapter of the Human Factors and Ergonomics Society

Annual Meeting in Soesterberg, November 1993

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CIP-gegevens Koninklijke Bibliotheek, Den Haag

Aging and Human Factors - Karel Brookhuis, Clemens Weikert, Jan Moraal & Dick de Waard (Eds.) - Traffic Research Centre, University of Groningen - ill.
Proceedings of the Human Factors and Ergonomics Society / Europe Chapter annual meeting in Soesterberg, November 1993.
With references.
ISBN 90-6807-311-7
Keywords: ergonomics, human factors, performance, aging

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Preface

This is the third in the series of Proceedings of the (HFES) Europe Chapter's Annual Scientific Meetings, based on the papers presented in Soesterberg on the 4th and 5th of November 1993. Since the Executive Council of the Europe Chapter has decided to stimulate release of a Proceedings from each Scientific Meeting, for reasons of stimulating attendance, the number of participants and the quality of contributions steadily enhanced. The Annual Meeting in Soesterberg and this Proceedings is an example of this assertion.

The Meeting in Soesterberg centred around *Aging and Human Factors*, and was organized in the honour of James Fozard at the occasion of his sabbath at The Center for Biomedical and Health-care Technology of The Eindhoven University of Technology. We are grateful to him and the other contributing authors of this Proceedings and want to thank all of them particularly for their patience and willingness to revise the manuscripts to our comments.

We owe special words of gratitude to the host of the Meeting, Prof. Jan Moraal, Fellow of the Europe Chapter, whom we are in dept for his hospitality and cooperation to the organisation of the Meeting. Finally, we wish to thank the TNO Human Factors Research Institute for hospitality and contributing genially to the meeting.

The editors

Aging and Work

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Abstract
Age-related declines in cognitive and psycho-motor capabilities very often do not show a direct relationship with task performance and productivity in real work. An important reason for this is that, apart from experimental shortcomings, older people use compensating mechanisms developed by experience and long-term adaptation to the task demands. Before predictions can be made regarding older peoples' performance, two things at least should be known. Firstly, one should know exactly what kind of capabilities the task is asking for. Secondly, a systematic database should be available with regard to age changes in functional capabilities. In tasks where the two are not related, one may uncover the characteristics of compensating mechanisms by systematic variation of task variables. Older people seem to have special difficulty with new and unfamiliar tasks for which no compensating mechanisms have developed as yet. Interface design, such that cognitive deficits can be overcome, and the development of training methods may lead to more easy adaptation and, consequently, employability.

Introduction
Members of the workforce have to adapt continuously to an ever changing working environment. Economic, technological, and social changes have a large influence on the kind of tasks people have to do and the structure of the organization they belong to. Tasks have changed largely from outdoor to indoor, from tasks requiring physical force to tasks requiring cognitive information processing capabilities, from simple to complex, and from easy to learn to more difficult to learn.
Being employed, one is confronted nowadays with unexpected calls for change, for flexibility, for preparedness to become (re)trained, and to accept different responsibilities. But also, due to reorganizations, many have to face forced turnover, unemployment, or early mandatory retirement.
In such a situation it is understandable that the management looks for a labour force that is qualitatively and quantitatively effective. Competition comes in or becomes more strongly, and those who cannot speed up with the rest will have to face more and more difficulties.

Among the last are to be mentioned the handicapped, ethnic minorities, less educated people and, of course, older employees. The last category, which is of interest here, often is seen as including those that have to make place for younger people, with a fresh education and having access to the latest developments in knowledge and technologies. Older people are mostly seen as not being flexible, having only outdated knowledge, are slow and difficult to move to other functions, because they cannot be (re)trained easily.

These are some of the reasons for which they are very often bypassed for promotions. So, the elderly that still are part of the labour force often meet serious difficulties to maintain their places. They are simply not seen any longer as potentially successful, and because of "their declining capabilities" excuses are obtained to dismiss them or otherwise to end their career.

Now, in this contribution we would like to focus on the question of "declining capabilities" and ask ourselves what, given the research literature, we really do know and what we don't know, and as such has still to be investigated; in other words, what is fact and what stereotype? If we have a more clear picture, the next question to be answered is what the possibilities, measures or technologies are that may compensate for declining or even uncovered capabilities. The basic point of view here is that we have to clearly differentiate between what we are inclined to think of older people's behaviour and what we really know from empirical research, and that there is no *a priori* reason not to make best endeavours to encourage labour participation of any kind.

On declining capabilities

From empirical research it is known that during aging various capabilities and skills show a decline. However, most research comes from the laboratory, where people are very often confronted with unfamiliar tasks on which performance is measured only after some hours of practice. Problems arise when we have to translate those results to real-world tasks and environments. Evidence exists that, although specific capabilities show a decline when becoming older, these negative effects not always prevail.

The following questions, then, seem to be justified, when we talk about declining capabilities:

- Which capabilities do we mean exactly?
- What kind of tasks call for these capabilities and under what circumstances?
- What is the amount of "loss", and can we measure it?
- When is the onset of a loss and with what speed does it develop?
- Are there any other factors besides age that might be responsible for any observed loss?
- What do we know about compensating mechanisms that might prevail over any kind of loss of capabilities?

Amongst the declining functions due to increasing age the following can be mentioned: visual functions, hearing, muscle force, working memory, speed of reaction, spatial cognition, stamina, the ease of processing complex/confusing stimuli, and attentional capacities. (For an overview see Welford, 1985.)

Most of these functions have been investigated in laboratory situations and not seldom, not to say nearly always, some variation of the following figure emerges as a result (Fig. 1).

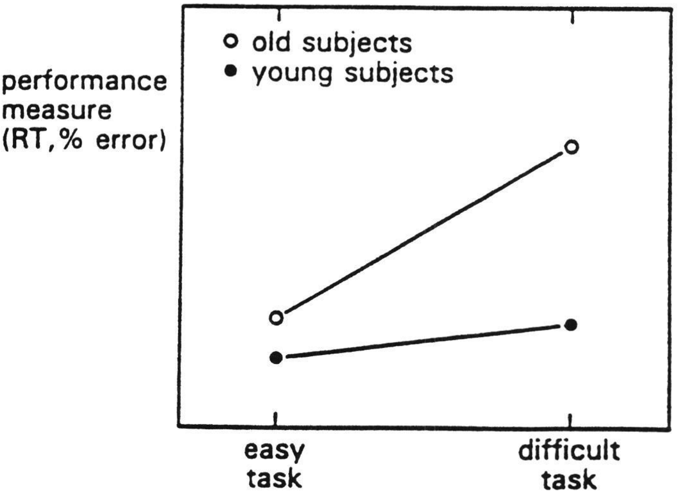


Fig. 1 Generalized outcome of laboratory experiments in which age groups are compared.

Fig. 1 shows, as a general picture, an interaction between task difficulty and age on a certain performance measure. Task difficulty may vary, for example, according to the amount of stress, whether the task is familiar or novel, the amount of practice or experience with the task, the complexity of the task, etc.
The conclusion from a figure like this is that older subjects do worse than young subjects, and when tasks become more difficult they significantly perform more worse than young subjects. Old subjects mostly show a much larger variation in results so that, even in cases where the interaction is significant, some of the older do even better than some of the young subjects.
Now compare Fig. 1 with Fig. 2 that is taken from a study by Salthouse (1984). According to Salthouse "... the numerous age-related declines in many aspects of cognitive functioning, and the general tendency for most behavioral activities to become slower with increased age lead to the expectation that the rate of typing also should slow down with increased age". However, what he found is shown in Fig. 2.

The typing task is compared with a laboratory choice-reaction time task, the latter showing clearly a drop in performance with increasing age in contrast with the results of the typing task. All subjects in the Salthouse study were experienced electric-typewriter typists with, on average, about ten years experience with at least 10-hr per week typing activities. Salthouse cross-validated this study by a second one and found practically the same results. Subjects in the study differed by between 80 ms and 150 ms in choice-reaction time between age 20 and 60, and yet the average interkey interval in typing was found to be nearly identical for 60-year-old typists compared with 20-year-old typists. Salthouse concludes that "... a dramatic discrepancy (...) exists between the results of traditional laboratory tasks and the performance of the real-life activity of typing" (Salthouse, 1984).

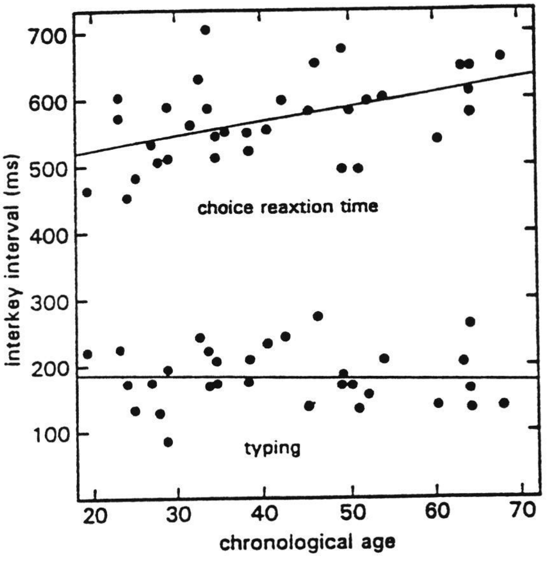
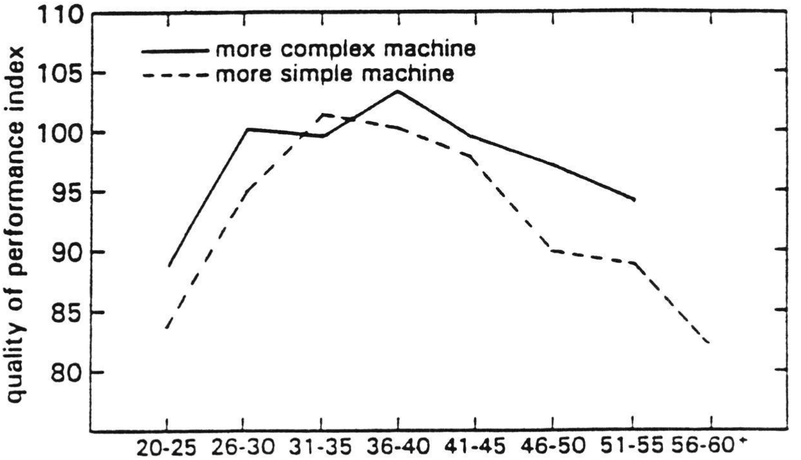


Fig. 2 Median interkey interval in milliseconds for the normal typing and choice-reaction time tasks as a function of typist age in Study 1. (Each point represents a single typist, and the solid lines illustrate the regression equations relating interkey interval to age.) (Salthouse, 1984).

Also from other sources conclusions are drawn that there is no one-to-one relationship between what are assumed to be basic capabilities and task/job performance (McEvoy & Cascio, 1989). The latter authors did a study on the basis of review of 22 years of articles published in 46 behavioral science journals, in which 96 independent studies were found reporting age-performance correlations. The total sample size was 38,983 representing a broad cross-section of jobs and age groups. Meta-analysis procedures revealed that age and job performance generally were unrelated. Interestingly, the study showed that neither the type of performance measure (ratings *vs* productivity) nor the type of job moderated the relation between age and performance to any great degree. The authors conclude on the basis of their and comparable studies that "... there is persuasive cumulative evidence (...) that age is not generally related to performance across a wide variety of jobs".

A seeming paradox
Reasons for the different results between laboratory studies and real-life job performance are to be found among the following. First, shortcomings in experimental design, like the use of too small samples, performance ratings that are confounded by stereotypes, the mixing of jobs and work levels, etc. Second, the small linear relations found might obscure a curvilinear relationship between age and performance (McEvoy & Cascio, 1989). Fig. 3 from Davis and Sparrow (1985) is a good illustration in this respect.



	20-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60+
Skill level 1	31	135	194	188	100	67	25	6
Skill level 4	29	117	187	156	80	48	21	-

Fig. 3 The relation between age and quality of performance for two skill levels varying in complexity in a sample of service engineers. The table gives the number of individuals in the samples.

In many cases curvilinearity may not be so obvious as in Fig. 3, but of course could be significant.
A third reason for a lack of correlation between age and performance is, what is termed "selective drop-out" or "selective retention" (McEvoy & Cascio, 1989). That is, samples of older workers might not be representative for their age cohort, but are probably above average performers. Although the workforce is generally aging, participation in the labour force of people over 60 is declining due to several reasons. We may therefore expect that those staying are amongst the fittest and best performers of their age groups. This fact may be illustrated by the following figure (Fig. 4), included in the chapter by Davies and Sparrow (1985).

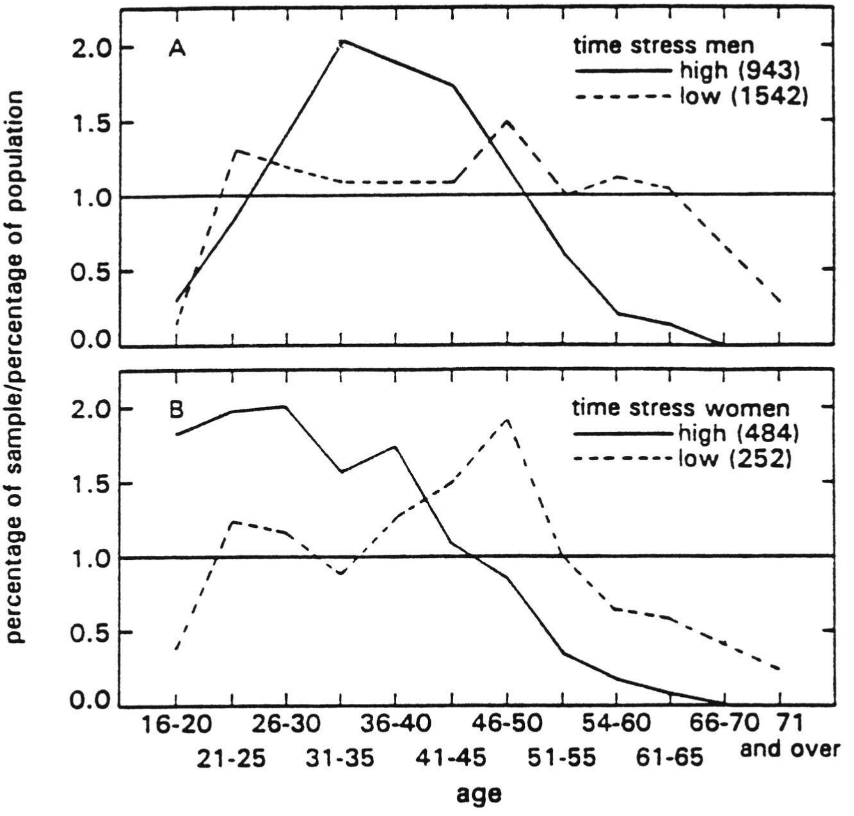


Fig. 4 The proportion of a sample of male (a) and female (b) workers in different age groups engaged in jobs involving relatively high (solid lines) or relatively low (broken lines) degree of time-stress relative to the proportion of men and women in that age group in the general population.

A fourth reason lies in our still insufficient understanding of "compensating mechanisms". Although basic capabilities may decline, older workers may profit from mechanisms that have developed over a longer time period so that they can preserve good labour performance. Amongst the sources of these are to be mentioned experience and overlearning, high motivation, positive identification with own work environment or organization, a lesser involvement in accidents, high job satisfaction, positive work values and, not seldom, high and effective productivity.

However, our understanding of how and in what way these factors influence performance, or in other words, what the basic mechanisms of compensation are, is only preliminary. The right question to ask then once has been formulated by Rabbit (cited by Salthouse, 1984) "... how in spite of growing disabilities, do old people preserve such relatively good performance", rather than "why are people so bad at cognitive tasks".

In his study on typing skill, Salthouse (1984) came upon a compensating mechanism that can explain why older typists preserve such good typing performance. Salthouse investigated the effect of preview window size on the rate of typing, i.e. the interkey interval, the results of which are shown in Fig. 5. The preview window, i.e. the number of characters that was shown from a 60-83 character sentence varied from 1-19.

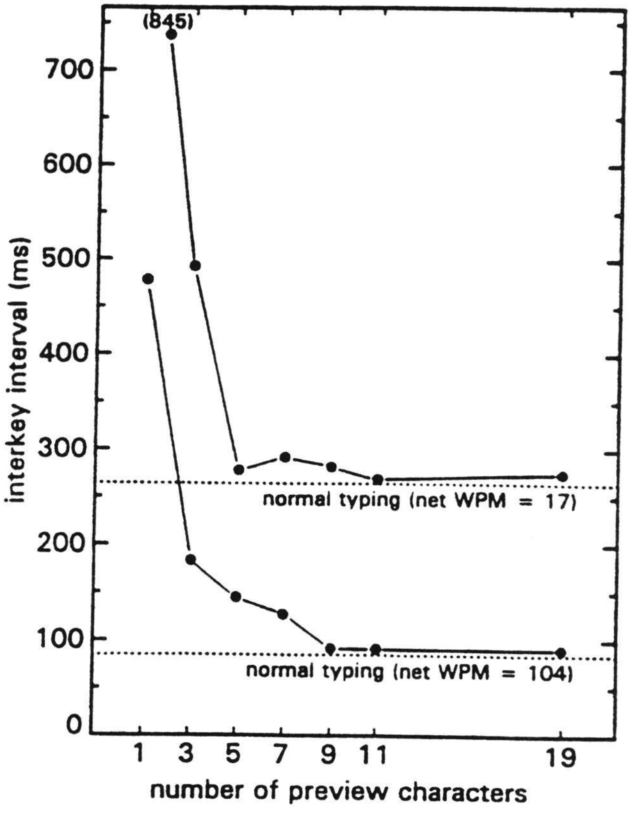


Fig. 5 Median interkey interval as a function of preview window size for the slowest (net words per minute [WPM] = 17) and fastest (net WPM = 104) typists in Study 1 (Salthouse, 1984). (The dotted lines indicate the median interkey interval during normal typing with unlimited preview.)

It is obvious that when only a small number of characters from the to-be-typed material can be seen in a single glance, anticipation of characters later in the material becomes impossible. Furthermore, because in typing anticipation works in parallel with the execution of perceptual-motor performance, i.e. making keystrokes, the whole process is slowed down. What is of special interest here is the preview window ´ age interaction, shown in Fig. 6.

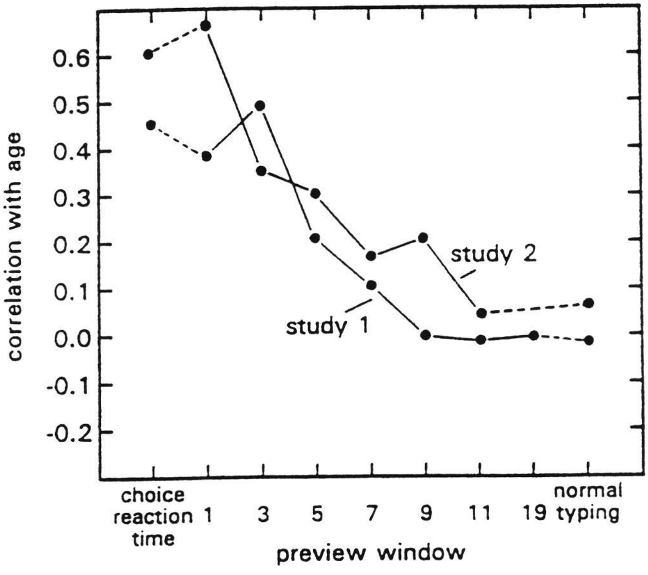


Fig. 6 Correlation coefficients between interkey interval and typist age across preview window conditions and the choice-reaction time and normal typing tasks (Salthouse, 1984).

When the typing situation is normal, i.e. no preview window such that anticipation of characters is not limited, there is no correlation between age and typing skill. However, the smaller the number of characters that can be anticipated, the larger the correlation with age. For older typists then, less characters to anticipate means a relatively more difficult task than for young typists. Anticipation of characters may be seen as the compensating factor for any decline in typing speed. Like the choice-reaction task in Fig. 6, which is an unfamiliar, unpractised laboratory task, one may conclude that, compared to normal typing, typing with less characters to be anticipated is a totally *different* task, in that it is new and unfamiliar. Evidence from several sources exist that the performance and learning of new and unfamiliar tasks poses special difficulties for older subjects. This will be discussed in the next paragraph.

Learning unfamiliar tasks

Czaja et al. (1986) studied the effects of three different training strategies on learning to use a word-processing system. Three age groups were compared (young: 25-29 years; middle: 40-54 years, and old: 55-70 years). All subjects had a working knowledge of a typewriter keyboard, but none had previous experience with word processing. Training strategies were on-line training, document-based training, and instructor-based training.

Although performance differed with regard to training strategy, no significant training condition ´ age group interaction effects were found. However, in a later study on age-group differences in learning to use a text-editing system, Czaja et al. (1989) found significant differences in learning success among the age groups when the same kind of training strategies were followed. Younger learners proved to be the most successful.

Fig. 7 shows that older learners receiving computer-based training made relatively more errors than the other age groups. However, the seeming age group ´ training condition interaction was not significant.

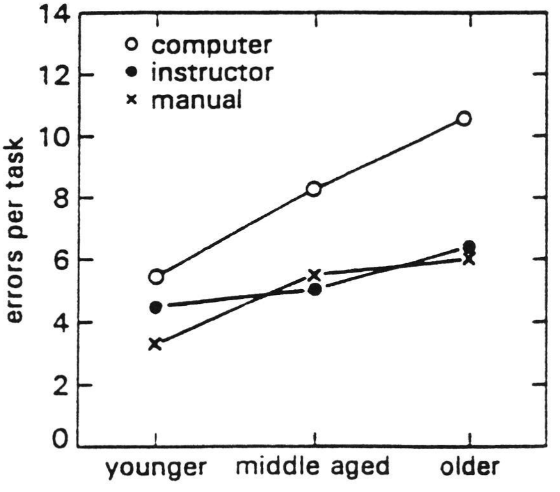


Fig. 7 Errors per task by age and training condition (Czaja et al., 1989).

On average, older people who received on-line computer training spent more time on average per task than middle-aged and younger subjects but, also, the age training condition interaction was not significant (Fig. 8).

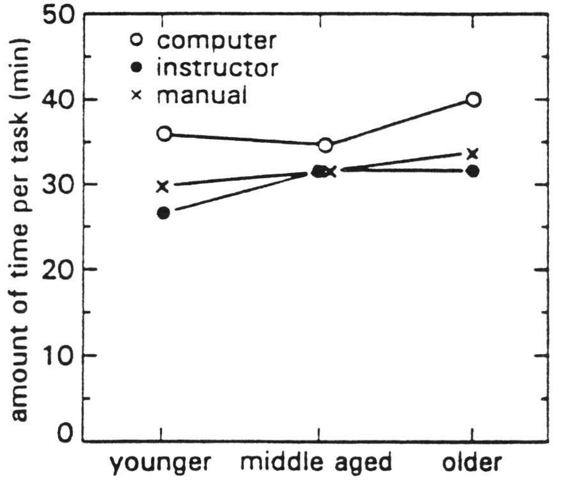


Fig. 8 Time per task by age and training condition (Czaja et al., 1989).

Czaja et al. (1989) concluded that the results of their study are consistent with those of other investigations; older people meet more difficulties than younger in learning to use a text editor. In general, it appears "that older people may have difficulty in acquiring the necessary skills to use current computer technology and are therefore at a disadvantage in work settings. Not only are their employment opportunities negatively affected, but the commonly held stereotypes about older workers not being able or willing to learn are reinforced" (*ibid*). By further analyzing the sources of difficulties older people meet, new training strategies could be developed for improving employability.

Czaja et al. (1989) point to the following possible sources of difficulty. The computer-based training strategy created a more passive experience than the document-based and instructor-based experience. As older and middle-aged subjects made more format-errors than younger subjects (including errors in spacing, reforming the page, setting of margins and tabs), it seems conceivable that the older and middle-aged groups did not conceptually understand the difference between using a typewriter and a text-editing programme; knowledge about the first is not appropriate for the last that needs a different mental model with the user.

Another reason in explaining the results is, according to Czaja et al. (1989), age-related differences in spatial memory, that seems to decline with age. Spatial skills are necessary in controlling how text appears on the screen. Training in spatial information processing might be helpful in improving older people's interaction with computers.

A third effect making it more difficult for older people to interact with computers is the loss of working memory, making it difficult to use menus. Relating menu title with menu information sometimes may go beyond subjects' capabilities in generating associations.

A thorough understanding of the declining cognitive abilities *that are relevant* for a certain task may help in the development of intervention strategies, e.g. adapted learning situations.

In a recent study by Czaja and Sharit (1993), it also was investigated what the extent was to which age had an impact on the performance of computer-based work. Three simulated real-world computer-interactive tasks were used, varying in complexity and pacing requirements. Subjects were 65 women, ranging in age from 25 to 70 years. Previous computer experience and age had a significant impact on the performance of the three tasks. Increasing age correlated with longer response times and more errors. In general, older subjects took longer to complete the task problem, a finding that is consistent with the general phenomenon of increased slowness with advanced age. This seems to be associated with the result that unpaced work demonstrated greater variability in the task, suggesting that older people prefer to work at slower variable pace. Furthermore, advanced age correlated with the number of perceptual-motor errors as well as decision errors, probably due to deficits in working memory.

The results of this study clearly have implications for training and interface design. Adapted interfaces that put a lesser burden on working memory, may be helpful and lessen the anxiety of older people for this technology.

What should be done?

It is well known that aging brings a decline in physical capabilities, like strength, muscle force etc. If we want older people still to be able to continue in physical tasks, the physical demands of the tasks should be lowered and adapted to the older workers. However, the same holds for perceptual-motor and cognitive abilities, where it is often much more difficult to uncover the critical capabilities. This should be done by careful task analysis. Variation of certain task variables, like in the typing study of Salthouse (1984) might uncover also the mechanisms by which older people compensate for declines. On the other hand, laboratory studies are very helpful in studying basic cognitive capabilities and their development with age, as long as we do not intuitively assume that these capabilities always directly determine performance in real-world tasks.

Our performance should include then the study of capabilities *in the laboratory*, as well as *real-world task performance*. The (lack of) relationship between the two could enhance our understanding of compensating mechanisms.

From an ergonomic point of view, tasks, workplaces, and work environments should be adapted to the capabilities of the workers. In the case of older people we are only in the beginning in that respect, especially when it concerns new and unfamiliar tasks. On the other hand, adaptation of the worker to the task situation by training, instruction, etc., is a second important instrument to increase employability.

Both, ergonomics and training, however, can only be successful with a thorough understanding of the capabilities that are critical.

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Suggestions for further reading

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Gerontechnology: matching the technological environment to the needs and capacities of the elderly

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Abstract
The new professional area 'Gerontechnology' includes the development of techniques and products, based on the knowledge of aging processes, for the benefit of an optimal living environment and adapted medical care for the elderly. In this new professional area, needs must be identified. This requires increased knowledge regarding activities of the elderly, problems engendered by these activities and the use of technology by the elderly to solve these problems. Demographic and epidemiologic data are required.
In the interaction of the human being with the technical environment, the processes of perception, cognition and motor action are determined by the qualifications and skills of the individual person. The possible communication of the individual with the environment, which exists of products and services is determined by the quality of the motor, cognitive and perceptual interface. Here, an increasing gap arises between the range of suitable products and services and the skills of the elderly. To bridge this gap, is the challenge and basis for the fundamental and applied research projects as they are developed at the Eindhoven University of Technology. The paper highlights projects dealing with mobility, communication, housing and health care for the elderly. A short description of the post graduate course is given. The intention of this paper is to create openings for international collaboration in research and training in the field of Gerontechnology.

Introduction
Imagine yourself when you are 60 or 80 years old. Will you be able to do the things you do now, for example your favourite hobby or even simple things such as reading the paper, taking a bath, turning on the stereo, driving a car or taking money from a cash dispenser? Where will you live, in what kind of house? Will you be able to enjoy new freedom from a life of work? For those of us who are still young (and who is not), will we go from mastering the high technology multi media systems coming on the market and making them our center of home entertainment and personal telecommunication, go into an old age incapable of dealing with anything beyond this last great accomplishment.

Or will we find ways to comfortably and continually adjust to the "next generation of innovations" in our world and be able to competently program the VCR's or what-have-you of the future as well as our grandchildren.

When asked, old people say that maintaining their independence is very important to them as they grow older. Indeed, independence is a quality of adult life in our society that we cherish at any age. To be able to live independently and to be able to do what you want depends partly on your health and abilities but also on the relevant social and physical environment. A supportive environment can help people continue doing what they are accustomed to and want to do even though they may perhaps see or hear less, move with more difficulty or have somewhat poorer memories. The social part of a supportive environment consists of people (family, friends or professional care givers) who provide help. The physical part includes technology that makes life easier and more enjoyable.

Throughout life, technology helps people with products (hardware, software and services) that provide a larger range of possibilities in perception, communication, information processing and/or mobility and helps maintaining health. Technology is acquired to meet daily needs when it is useful and available at a reasonable cost.

We believe that there is a gap between the needs for technology by the elderly and the range of suitable products and services available for them. The existence of this gap is well illustrated in earlier attempts of researchers (NATO conference, 1983), designers (ref. Pirkl, 1994), assessment panels (OTA report "Technology and Aging in America, 1985) and surveys by the European Union (Cullen & Moran, 1992, Oster, 1993). The gap between the needs of the elderly for technology and existing technology itself has two parts.

First, many existing technologies have to be adapted for use by the elderly because perceptual, cognitive and mobility limitations that often occur with aging make today's technology difficult to use effectively. The problem that must be addressed here is not the function of the technology but the interface between the technology and its user. A good example here might be the Liquid Crystal Display technology. Some environmental conditions (glare) and users (visually impaired) make that these types of displays are not always suitable.

Second, most existing technology does not specifically address the unique challenges (illnesses and limitations of activity) or the opportunities (time for new activities and interests) of the elderly of today and in the coming years. The problem that must be addressed here is the challenge of adapting new technology specially oriented towards the interests and special needs of the elderly in the coming years. We might want to think here about total new concepts of private transport that can use both gasoline and metabolic energy. (The Dutch 'Spartamed' is a good example, but we can be more creative)

There are two major influences on the gap. First, there is the ongoing demographic change in the age distribution of the population. The relative number of older people will continue to increase through the middle of the next century. At the same time, particularly since the post World War II "baby boom" there has been a relative decrease in the number of teenagers. The percentage of people older than 65 years in the Netherlands was 6% in 1900, 13% in 1989, and in 2030 it will be approximately 21%.

What influences the gap as well is the ever increasing pace of the density and speed of technology development itself. The current increase in the complexity and speed of information processing and communication technology and the increased sophistication of automobiles and other modes of transportation illustrate these changes.

This means that adults of all ages will be confronted with an ever more rapidly changing technological environment that will continue.
Closing the gap between elderly and technology is the goal for the program that is under development at the Eindhoven University of Technology. We call the program Gerontechnology; technology for the aging. Our goal is to support and encourage education and research in this area throughout this university and to promote research and development activities in other educational, industrial and health care facilities in the Netherlands and other countries.
The gerontechnology program is a natural outgrowth of ongoing educational and research activities at the Eindhoven University of Technology. Both within specific departments and in interdisciplinary centres that cut across these departments there are several ongoing projects that provide a basis for the new development. Specifically, the interdisciplinary Centre for Biomedical and Healthcare Technology is the setting in which the gerontechnology program is being developed. This centre supports and connects research within a variety of technical programs in human perception, healthy buildings, electrical engineering applications in medicine, biophysics, biochemistry and other areas, all in collaboration with the specific faculties of the university. The centre has conducted an international conference on gerontechnology, edited a book on gerontechnology (Bouma & Graafmans, 1992), developed a post graduate course on the topic which will be given for the first time in November this year, and is supporting several research projects in collaboration with specific faculties. Current developments include the creation of the Institute for Gerontechnology Research at the Eindhoven University of Technology with a full scale graduate level education and research program.

What is Gerontechnology?
The term, gerontechnology is a composite of two words: "gerontology"; the scientific study of aging, and "technology"; research and development of techniques and products. Gerontology is concerned with research on the biological, psychological, social and medical aspects of aging. Technology includes both research and development derived from chemical, civil, construction, electrical, industrial, information, mechanical and physical engineering. Gerontechnology refers to research and development of various techniques and products based on a scientific knowledge of the aging process. Gerontechnology includes technology that supports basic and applied research into aging processes, for example imaging techniques, or signal processing of brain activity. More formally, gerontechnology is defined as the study of technology and aging for the benefit of a preferred living and working environment and adapted medical care for elderly.
The word gerontechnology was introduced by the first author (Graafmans & Brouwers, 1989) who is more than happy to observe that the term is adopted by many research groups all over Europe and the USA, not because the word in itself is such a beauty but because of the fact that it covers an arena of interdisciplinary

scientific activities that deserve and demand for our attention. If we are self-centred enough we will invest in our own future.
In gerontechnology as in gerontology, we recognize that the difference between normal aging and falling ill is important.

The starting point for gerontechnology is technology developed for or adapted for the elderly. Aging may well be accompanied by illness so consideration of the illnesses of the elderly is part of the research needed for gerontechnology, especially when a sickness occurs mostly in the elderly or when it has special effects on them. For example when a young and old adult have the same medical problem such as a broken hipbone or pneumonia, the recovery period is often longer, the symptoms are usually more severe and the older person is more likely to have concomitant medical problems that complicate treatment and recovery.

What is the goal of Gerontechnology?
Designers of products, systems or processes must be aware that human performance changes with age and must adapt their design to elderly user characteristics. This is a simple goal to state but it is not an easy one to reach. Knowledge concerning aging must be translated into products that must then be produced. Gerontechnology encourages designers and engineers to join in translating the multidimensional needs of the older consumer through research programs into product development and the market. The results of gerontechnology will include better communication and interaction between elderly persons and their environment and assistance in maintaining control over it.
Gerontechnology can address aging in the same five ways as human factors and ergonomics do in the way as described by Fozard (1994). Gerontechnology also plays a role in:

- prevention
- compensation
- enhancement
- aid to caregivers
- improve research on aging

Gerontechnology basically covers the same field as human factors or ergonomics and aging, but it is restricted to that research and those applications where technology plays a role. On the other hand it is broader than human factors and ergonomics if we look at the crossroads of medical technology and aging in for example diagnostics, treatment and care support in the case of chronic diseases, many of which come with age. Gerontechnology also adds the economical factor since it aims at affordable technology and last but not least it adds the psychosocial factor by looking into the preferences rather than the needs of the elderly. If the in-depth analysis of man-product-environment interaction is characteristic for human factors and ergonomics then gerontechnology distinguishes from human factors by focusing on:

- technological support in aging research and
- synthesis of results of research in design

Gerontechnology's target groups: The aging and the aged

People of all ages use technology to make it easier to carry out their activities. Over a period of generation the design and technology of the home for example might support a new family with adults, children, and perhaps grandparents.

Later it will be an empty nest for parents whose children left home, and still later frail elderly parents with impaired mobility, sensory function etcetera will prefer to find a comfortable shelter in that place. At the same time secular developments in technology itself may profoundly affect the ways in which the home as such may be used and what devices people might wish to use in their home.

The scenario just outlined calls for a lifespan approach to design which would emphasize flexibility and adaptability of the architecture and technological environment of the house to meet the changing needs of the occupants. The adaptability would be reflected in the structural characteristics of the house (such as removable or movable interior walls) as well as the interface between the user and the furnishing and appliances (such as the placement of cabinets and the controls of appliances).

What about technology for the present elderly? Sharing a common chronological age does not make for homogeneity among the elderly; indeed the opposite is true. Differences in genetic background plus differences in life experiences, exposure to diseases and differences in lifestyle make for relatively greater heterogeneity among elderly persons than younger ones. Note that is not stated here that there exists a genetic difference between young and old persons. Even though there is no single elderly group, some age-graded classification of the elderly is useful. One subgroup would contain persons up through about 75 years and containing about 90% of the elderly that is general healthy. They would benefit from adequate consumer products and services that enhance work and new technology that would improve performance of leisure, work and family activities that are unique to this period of life. A second subgroup can be distinguished between 75 and 85 years, that may need some assisted care to remain independent, which could be met by technology. A third subgroup over age 85 would typically need more assisted living and medical care, for which some of the technology would derive from existing medical technology.

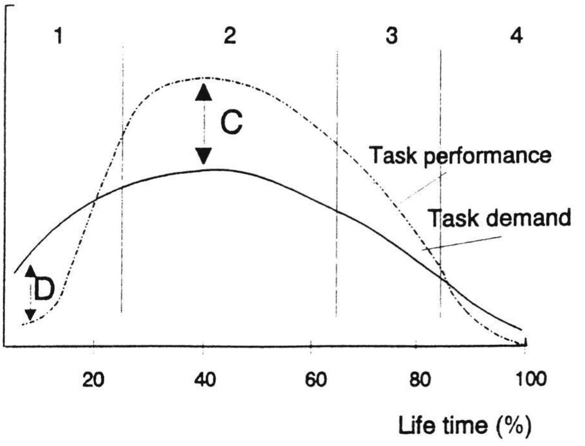
In summary, the target groups for gerontechnology define a need for a developmental or sustainable approach to technology, as well as adaptation of existing technology and development of new technology targeted toward the interests and special needs of older persons. The adjective 'sustainable' refers to the economical and ecological criteria for technological developments, as mentioned in the report of the World Commission on Environment and Development: Our Common Future (Brundtland report); Oxford University Press. (1987). The Eindhoven University of Technology has adopted these criteria in its mission statements for the coming decade.

The conceptual basis of Gerontechnology

Three concepts are central to gerontechnology:

- The first is that age-associated differences in functioning are modifiable by technical modifications in the environment. A task that may seem very difficult to an elderly person in one situation may be easily accomplished with suitable environmental modifications. Thus the very idea of age-grading of abilities should not be considered independently of the technical environment.
- The second is that the level of human abilities relatively to most task demands changes over the lifespan: increasing from childhood to adulthood, remaining stable over most of the adult years and then declining in old age.
- The third is that greater exposure and hence familiarity with particular display/control configurations that may occur with aging increases adaptation to those configurations and reduces the ability to adapt to different configurations....It is harder to unlearn than to learn.

These concepts fit very well in the dynamic systems model as introduced by Fozard (1994).



Relation between task performance, task demand, comfort and demand during human life

Here, we want to give an example in order to illustrate the complexity we are facing as researchers and designers. It is known that information about the environment comes from many external and internal sources through a variety of input modes.

- visual 83%
- auditory 11%
- smell 3.5%
- touch 1.5%
- taste 1.0%

Note that in this list some modes are not included such as, kinaesthesis, temperature, vestibular, etc. We also know that memory retention of newly learned information depends on the mode of information input and on the time elapsed.

MODE \ TIME ELAPSED	3 HOURS	3 DAYS
AUD.	60	30
VIS.	70	40
A/V	90	70

These data originate from industries, involved in communication and information technology (audio-visual systems). However, they are an average of large populations and do not take into account variables such as:

- age
- past experience (training and education)
- present state of body and or mind
- speed and density of the information process

The current research of Bouwhuis, Brouwer and McCalley at the Institute for Perception Research of the Eindhoven University is aimed at gaining more insight about the impact of these variables on the design of products dealing with information processing. We do know that hundreds of researchers, all around the world, are engaged in the same kind of activity. However, the integration of the results of this research is as complex as in the Human Genome Project.

Gerontechnology at the Eindhoven University of Technology

Historical background

The impact of age-related physiological and psychological changes on human functioning in the living and working environment is the common theme for the development of this program at the university: gerontechnology as a field of academic knowledge, an interdisciplinary program of research, and initiation of a process of technology and knowledge transfer between the university and industry and other institutions.

The development of gerontechnology at the Eindhoven University of Technology began in the late 1980s. The major university initiatives in gerontechnology have been organized in the Centre for Biomedical and Healthcare Technology (BMGT). The first major milestone in developing the research and educational plans for gerontechnology was the planning and convening of the first international conference on gerontechnology in August 1991, and the publication of the first book on gerontechnology.

During the 1993-94 year, an independent Institute for Gerontechnology Research will be founded. The institute is the focal point for the development of the academic discipline of gerontechnology and will provide the integrative power necessary to organize and coordinate education, research and development and knowledge transfer in gerontechnology within and outside the university. Because the university's Institute for Gerontechnology Research is the first in it's kind, it will be critical in establishing relevant cooperative programs with other universities, institutes and industry, both within the Netherlands and internationally. The Eindhoven University holds the co-chair in COST-A5, which is a European network on 'Ageing and Technology'. Fifteen European countries (EU & EFTA) participate in this network

Education and curriculum development
The development of an interdisciplinary knowledge base for gerontechnology is a primary task ongoing at the university. Training of a small core of researchers and teachers of gerontechnology is a major goal. In 1993, the university appointed its first visiting professor of gerontechnology. Dr. J.L. Fozard, director of the National Institute on Aging Baltimore Longitudinal Study on Aging, is spending this academic year at the university. He helped establish the conceptual relationships between gerontology and gerontechnology, and to develop the curriculum in gerontechnology. By the end of 1993, a two day international postgraduate course on gerontechnology was organized and conducted at the university. The topics included the conceptual foundation of gerontechnology, business and economic aspects of gerontechnology, applications in cognition, perception, motor performance and anthropometry. Examples of gerontechnology applications in work, housing, and transportation were covered and a workshop on a design problem was included. A one day international workshop followed the course to evaluate the content and organization and was aimed at recommendations for future courses and workshops throughout the European community.

Research areas
Educational and research gerontechnology activities at the university have centred on four broad areas: housing and urban planning; mobility, transport and motor performance; perception, cognitive performance and communication; and health, health care and medical technology.
All of the research activities, that fit very well in the gerontechnology program, are carried out by research groups in most of the faculties of the EUT. The following enumeration will serve as example of the span of gerontechnology.
The faculties of Building & Architecture and Philosophy & Social Science are active in the field of housing and urban planning for the elderly. They participate in a consortium of European groups that submitted a proposal under the EC TIDE program about smart house technology(domotics). The objective of this project is to integrate multi-sensing techniques and artificial intelligence in a global housing approach to help elderly to live autonomously at home. They also are developing a model of personal needs and a standard program of demands on a flexible and adaptable housing environment for the elderly. A related topic of research is the thermal comfort of the elderly.

The laboratory for automotive engineering is doing research on a new concept for individual transport, based on the capacities and preferences of the elderly.
In the area perception, cognitive performance and communication several groups are doing research. The faculty of Industrial Engineering & Management Sciences introduces the age related changes in the research on task design and work schedules. The Institute for Perception Research among others is doing research on visual attention and its technical consequences. More applied research is carried out on communication aids and reading aids. One objective of the latter topic was to obtain better readable television-subtitling.
The faculties of Chemical Engineering, Electrical Engineering and Mechanical Engineering are doing various research projects in the areas of health, health-care and medical technology. The development of a diagnostic method for prostate cancer, which is an age-related disease, is a project in the faculty of Chemical Engineering. The effects of nutrition on ageing are studied in a biomolecular context by the same department. Other research topics in this area are the development of a fitness profile for elderly, age-related cardiovascular diseases and the modelling of muscle and bone.
In 1993 four doctoral training projects in gerontechnology were established at the university. The projects, summarized below, illustrate again the diversity and interdisciplinary nature of gerontechnology research.

A "COPD-proof" dwelling for the senior citizen
About 40% of the population is susceptible to allergic reactions of which approximately 25% will develop allergic symptoms. Long term exposure to allergens and years of asthma or chronic bronchitis may lead to emphysema. Reduced lung function may lead to decreases in mobility and functional independence. The aim of the project is to design, specify and maintain directives for new and renovated housing for the aging citizen. The indoor air should have a minimal load of irritating gasses and allergenic or infective aerosols. In this project the mass of known medical, chemical and biological data are reduced to key-figures for minimal development and spreading of pollution. These key-figures may then be used by the designers of houses. The key-figures will include hygienic thresholds including irritating gases and allergenic or infective aerosols, indoor air-pollution regimes, humidity management, temperature relationships and requirements for management of common pest organisms. While evaluating the published information discrepancies will be discovered that are to be resolved in new laboratory experiments.

An examination of the reasoning processes of elderly persons encountering new technology
The goal of this project is to study the reasoning and thinking processes used by elderly when they encounter new technologies. The major objective is to provide a generalizable basis of understanding from which responses of the elderly to new technology in their working and living environment can be predicted. The assumption is that people are not too old to learn to use new technologies when the concepts that underlie the design of these new products are closely mapped to their reasoning processes and match their life style and experiences. In order to accomplish such a

mapping, we have to know how the elderly reason and think about these technologies. The aim is to develop methodologies for studying the cognitive processes of the healthy ageing population.

Development, design and management of adaptable housing for independent living elderly

Elderly persons prefer to remain in their homes and familiar environments as long as possible. Ideally, their housing is based on knowledge of the changing mental and physical capabilities of the elderly as they age. The research question is: 'What kind of adaptable housing environment do the elderly need in order to continue living independently in a house as their abilities and needs change?' The study aims to develop a model of personal needs, a standard building programme of demands and a collection of design patterns on a flexible and adaptable housing environment for the aging and the aged. The information is expected to be used by organisations that develop, design and manage housing.

Neurophysiological and psychophysical effects of general anaesthesia on cognitive functioning in the elderly

The aim of the research project is to evaluate preoperative and postoperative neurophysiological and psychophysiological signals for early detection of neurological or cognitive damage in elderly patients during surgery. Neurophysiological signals such as EEG and evoked response measurements reflect the cortical and sensory pathway functioning and therefore allow detection of several types of brain damage. Psychophysiological techniques enable acquisition of objective and quantitative data about pre and postoperative cognitive functions. The emphasis of the study will be on the development of a set of neurophysiological parameters that allow intraoperative monitoring of neurological and cognitive functions.

Application of advanced signal processing and incorporating available physiological knowledge about the clinical importance is needed to enable success of such a study.

Design

The Eindhoven University of Technology does not have a design department. Knowledge transfer and implementation are accomplished through cooperation with industry and industrial design institutes. The university has close ties with several industries, particularly Philips Corporate Research through its Institute for Perception Research and with Philips Corporate Design. For example, designers from Philips and the European Design Centre will contribute to the first international postgraduate course in gerontechnology described above.

Coordination

The university, through the Centre for Biomedical and Healthcare Technology and now the Institute for Gerontechnology Research has played a central role in establishing and encouraging collaborative efforts in gerontechnology within the Netherlands and internationally. It hosted the first international postgraduate course in gerontechnology, and is the coordinating centre for a proposed multinational effort to create a European data base in gerontechnology. It has established collaborations in gerontechnology with other universities in the Netherlands. The coordination efforts are critical for the successful development of gerontechnology, because the required expertise is not all available in one setting. For example, the university has no activities in technology related to leisure activities, few in nutrition, and it depends on collaborative arrangements with medical schools for the medical and health care research and training activities.

In summary the gerontechnology program of the Eindhoven University of Technology is establishing curriculum and research activities both within the university and in collaboration with other institutions within and outside the Netherlands. It is cooperating with other organizations to establish data bases appropriate to gerontechnology and to encourage industrial design projects that reflect the goals of gerontechnology.

We wish to end this paper with an anecdotical warning for future researchers in gerontechnology.
TOO OFTEN, IT HAPPENS THAT AN EXPERIMENT HAS BEEN SET UP OR A PROTOTYPE PRODUCT HAS BEEN DEVELOPED WITHOUT PRIOR INVOLVEMENT OF THE ANTICIPATED ELDERLY USER GROUP.
TOO OFTEN, IS HAS BEEN PROVEN THAT THE EXPECTATIONS OF THE ACADEMIC RESEARCHER OR THE INDUSTRIAL DESIGNER WITH REGARD TO USER REQUIREMENTS OR USER BEHAVIOR DO NOT MATCH WITH USER CHARACTERISTICS, ATTITUDES AND PREFERENCES.
TOO OFTEN, THIS IN THE END LEADS TO A FRUSTRATION OF EITHER THE RESEARCHER AND THE DESIGNER OR THE BUYER AND (NON)-USER.

The deeper morale of this warning is that researchers, engineers and designers are very likely to have a completely different image of the elderly and their lifestyles than the one the elderly have of themselves! We should strive for a market-in instead of a technology push approach. Only this can lead to a situation where buyers indeed become users.

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Elderly´s management of job career

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Abstract
Today´s labour market is characterized by frequent changes of employment and life long employment in the same position is rare. Elderly may be particularly exposed to the consequences of such mobility, both with regard to coping with change and utilizing its possibilities. How the situation is handled might also contribute to what usually is termed well-being, life satisfaction and life quality. Within this context the present study addresses the following questions: Which individual qualities are beneficial for a satisfying solution of job change? How does individual qualities interact with work, career and family to come to favourable solution? Knowing personal characteristics, can individualized counselling improve the outcome?

Ten middle-management executive employees in a major Swedish company were tested for personality qualities, locus of control, coping strategies and life satisfaction and they were followed for five years. During this period, each member of the group had access to a personal counsellor with psychotherapeutic competence, who met with the client between 1-3 times a year at the client's initiative. At this meeting the client's general situation including work, employment and family was reviewed and the individual issues were worked through. The counsellor had full knowledge of the individual baseline data and could tailor his intervention individually based on this information and present conditions. At the three year follow-up all clients had changed employment one or several times, with different outcomes. Some had made a work career, some had adapted, some had made new priorities and some had a status quo situation. The life satisfaction at follow-up could be related to the initial assessment and tentatively the individual support from counselling is assumed to have contributed to the outcome.

Introduction
Today´s labour market is characterized by frequent changes of employment and lifelong employment in the same position is rare (David 1993). It is a rule rather than the exception that assignments change one or several times during a job career. This is probably true for all positions also for executives at the middle management level. There might have been a change in the aim and direction of the enterprise or changing methods, changing organisation, changing values, and changing management. Sometimes it is a question of time limited leadership that should be terminated according to contract. New and so far untested careers may be attempted;

there may be a transition into a specialist career, to consulting or mentorship. Growing old might imply increased exposition when it comes to coping with change (Hagberg 1990) or taking advantage of or even profit from the possibilities that lie in these job changes (Ranning 1986, Featherman et. al. 1990, Kruse 1990). For some it may be another step on the career ladder, for some a necessary step forced by circumstances beyond the responsibilities of the employee, for instance health deterioration, take-overs from bigger companies etc. For some it means a possibility to take up relations again with the family which has been pushed to the margin during a career and professional development. Job changes might also give a possibility to take up contacts with people or hobbies that could not be combined with a tight calendar.

Taken altogether, the solution of such a change might contribute to what is generally called well-being, life satisfaction or life quality (George and Beron 1980). Basically, those concepts have a particular individual and personal meaning and in most cases, they are achieved in very individual ways. A number of things are particular for those concepts:

First of all, they are subjective, i.e. they exist mainly in the eye of the beholder (Naess 1987) .
Secondly, they are related to the value of relations, objects, conditions and circumstances that can only be determined individually (Antonvsky 1990).
Thirdly, they are also an expression for to what extent the individual has a capacity and the environment allows satisfaction of needs of great importance to the individual (Svensson, 1991) .
Fourthly, they refer to the future time perspective, i.e. to what extent the individual sees a possibility to fulfilment of his ambition in the future (Kruse 1987).

Life quality could, of course, be studied in relation to different contexts. In this case, it is studied in relation to work, family and individual characteristics in persons of middle age, who are exposed to the forces of a changing labour market. Among the different aspects of life quality the present study focuses on present life satisfaction as experienced by the subject at a specific occasion. Tentatively, related variables are considered to be personality characteristics, locus of control and coping strategies and the efficiency in using the coping strategies.

Three questions are of major interest:

- Which individual qualities, foremost personality characteristics, can be shown being important to retained or to improved life satisfaction.

- Secondly, how does individual qualities interact with changes in work and career in the middle-age to maintain life satisfaction.

- Thirdly, knowing psychological characteristics of the individual, can psychological interventions be shown to support or increase life satisfaction when changes occur in work career.

The present study examines a group of middle management directors who at baseline were comprehensively assessed. Based on this examination individual interventions were made regularly during three years. During these three years, there were for some of the subjects radical changes in working situation as well as in family relations and at follow-up, three years later the outcome was related to the initial assessment at baseline.

Subjects and methods

Ten male middle-management executives with an age range of forty-five to sixty years employed in a major Swedish paper producing company, were assessed at baseline using the following instruments:

Lifespan interview (Hagberg 1994) focusing on the evaluation of the relation to significant others during the different lifeperiods.
Work structure interview giving the organizational context of management with special reference to influences on decision making.
Personality assessment with percept-genetic techniques, MCT. (Smith 1961). This test evaluates personality in terms of ego defence mechanisms and maturity .
Life satisfaction (Neugarten 1961). According to Liang (1984) and Adams (1969) this dimension is categorized in three ways: mood tone, zest for life and congruency between desired and achieved goals.
Locus of control (Flemming and Spooner 1985) using a questionnaire and collapsing the original five factor model into two concepts: belief in internal or external control (I/E).
Coping strategies (Hagberg 1990) are assessed during the lifespan interview, in which critical life events are identified and strategies for handling them are reported.

Individualized interventions were made, starting with a feed-back of baseline assessment, after which pros and cons were examined and followed up in a dialogue during the three years. During this period each member of the study group had access to a personal counsellor with psychotherapeutic competence, who met with the client 1-3 times a year on the client's initiative. At this meeting the client's general situation including work, employment and family was reviewed and individual issues were worked through. Support was given to planning of job-career and alternatives were discussed with the client's unique personality characteristics in mind.

The enterprise, in which the subjects were employed, was subsidiary to a major paper producer in Sweden. The main objective was sales and distribution. It was characterized by a somewhat old-fashioned, authoritarian and hierarchical management profile. During the study-period the enterprise was taken over by the major paper producer and re-organized.

After three years, a follow-up was made and the subjects were visited for a personal interview. The interview is half-structured and covers the following areas: work situation, family relation, physical and psychological health, and present life satisfaction.

Results

Using qualitative methodology to categorize the subjects at follow-up in terms of work conditions, well-being and life satisfaction four different out-comes were naturally identified.

The careerists: Three persons had made a career in other businesses after the re-organization of the company and have there been promoted to leading positions in banking and trading companies. They worked hard, they had a good economy although there has been some critical phases in the family relations. They reported high present life satisfaction as expressed in mood, zest and congruency.

Are there in the baseline material predictors that separate this group from the rest? The answer seems to be affirmative. Both show in the personality assessment histrionic qualities with primarily repressive mechanisms of defence. One of them even a rather primitive hysteric disposition. Thus they seem to be attracted to actor-like appearances and they also feel good in performing their respective parts. In this case, it seems as the working role is the most important one. They are flexible and adjustable. Both traits which can work to their advantage when the enterprise was re-organized and they had to move on to another employment. Obviously, they have a strong ambition and a need to perform. Especially it is a satisfying experience to act in a executive position. It should be noted that both of them in their baseline results have high values on present life satisfaction and show the same results three years later. They both use active coping strategy, i.e. they rather work through, cognitively or emotionally important events or they use their work as a means to get through frustrating situations. So in a way, coping is work and work gives them a career and the career gives them self esteem and the career also makes them appreciated by others, which seem to be one key issue in their life satisfaction. They also have an internal locus of control which in previous studies has been shown to be an asset when it comes to stress control especially among elderly people (Krause 1986) .

The adaptables: For two persons, the present situation is characterized by a successive adjustment. They have the same position in the reorganized company as at baseline but they have now influence on the decision making as members of the steering group. It has been important for them to keep up working relations to earlier colleagues and they had moved together with them into new departments. They feel comfortable in the position. They put great value in family and relate to family, friends and acquaintances more now than previously. They like outdoor activities and they take interest in sports. They have some problems with their health or with a age related reduced endurance. There seems to be an awareness of increasing age and the limitations that are brought about by this process, which motivates the adjustment both in work and family relations. They score high on present life satisfaction in all three scales, i.e. mood, zest and congruency.

How does the present situation relate to the baseline results and how does it differ from the three earlier ones? In personality, there are traits of both immaturity, some anxiousness and less strong defence mechanisms. They both show a normal degree of neuroticism and one of them even to some extent evasive behaviour. In the other person a non-confronting way of handling conflicts seems usual. Both of them also show some degree of social dependency. The coping strategies fall back on principles and ethical norms which are used in a detached way. As the subjects in group one, they have an internal locus of control and they also have maintained a good life satisfaction score.

The reconsiderers: A cluster of two persons separates from the rest and has reconsidered their work commitment. In a way, they have slowed down and their commitment is now more on family than on job. They have transferred from the old company to the new one maintaining their old position, often motivated by the satisfaction to work together with the same people as they used to. There is a marked increase in family commitment and in a wider sense social contacts outside the work. Both had a low score on present life satisfaction at baseline and at follow-up it is still low. Especially noteworthy is the reduction in the mood tone which suggests a possible depressive quality in their character or a depressive way of reacting.

Are they different from the others in the baseline result? First of all, there is a weakness of identity coming in one case from less strong ego structure and in the other case a hint of androgenity. They also differ from the previous two groups in being outward directed, i.e. believing in an external locus of control implying less sense of self control on things that happen to them. The adaptive strategies are characterized by anxiousness and alienation. Both chose in the coping interview as important life events job related incidents. Thus it could be concluded that they still regard work and performance as significant. However, they seem to have difficulties in handling their job situation. On reflection, it seems as the two subjects in this group do not feel being in control of the changes that occur, rather being in the hands of circumstances, which they do not feel strong enough to endure and than turn in other directions for life satisfaction.

The bewildered ones: Two persons in this group can be characterized as confused as to what to do, trying to keep on to status quo but actually on the way of being marginalized. They have had difficulties in finding their place in connection with the re-organization. One has finally acquired a staff position and is doing computer development and the other one has started as a consultant dealing with management issues and staff development. Their work situation is described as chaotic. The family relations have been broken and on a temporary basis new relations are formed. There has been decline in psychological health and an onset of psychosomatic symptoms. These two persons have the lowest life satisfaction scores, foremost in the congruency dimension, i.e. they are discontent that things did not turn out as they were planned and this perspective of life seems to have a somewhat dominating influence of their present way of thinking.

What make the bewildereds different from the others? Both of them have the most frequent negative signs in the personality assessment. In one case, it is clearly a borderline structured personality and in the other case, there is a dominance of the compulsive defence mechanisms (isolation and denial), that might even cover up a more severe psychiatric condition. They also show low life satisfaction now as well as at baseline. While one shows an internal locus of control, the other one scores low on external as well as internal control which tentatively might be interpreted as lack of control. They both score low on life satisfaction at baseline. At follow-up they are still low except on mood tone which has improved during the study period.

The intervention / the counselling

One of the authors (ÅA) has been available during the whole three year period as a talking partner. At least once a year an individual session has taken place. In some cases there has been a more frequent contacts at the client's initiative. Also one group session has taken place at a retreat, when gerontological issues with special reference to work and career were presented and discussed in general as well as in relation to each client´s specific situation. The intervention/counselling can not at the present time be related to the individual client. However, it could be stated that it spans from supportive psychotherapy with its bases in the initial interview to practical advice as for necessary training and career development. The general purpose of the intervention has been to increase the awareness of ageing related problems and possibilities, to focus upon individual problems in relation to personality qualifications and previous work experience, to support coping strategies in order to deal with age related changes and to promote a holistic view of the situation at hand.

Conclusions and discussion

The present study is qualitative in nature. The number of subjects are small but intensively investigated. The results are primarily descriptive and will form hypothesis for future research. There are some tentative conclusions to be drawn out of the study.

To begin with, it is possible to identify different patterns when data from both baseline and follow up are combined. These are the careerist, the adaptables, the reconsiderers and the bewildereds. The first two score high on life-satisfaction, the other two score low. Each group shows a somewhat different personality profile at baseline. If judgement is based on life satisfaction, the outcome is more favourable in the first two groups. These two show in addition to high life satisfaction also maturity in personality, autonomy, internal locus of control and active behaviour/cognitive coping strategies. These are qualities agree well with what is known from gerontological research (Baltes 1990) and stress management (Lazarus Folkman 1984) to be prerequisites for successful ageing.

Successful ageing should also, of course, include a capacity to deal with changes that are related to work and work environment. Satisfaction with how the combined effects of both job changes and changes brought about by ageing are managed, has been the focus of the present study.
Most interesting to find is that the life satisfaction scores in terms of mood, zest and congruency are stable for all subjects independent of personality profile, what kind of change that occurred and degree and kind of intervention. For careerist and adaptables life satisfaction was high and for reconsiderers and bewildereds it was low through out the period. This finding could be interpreted in several ways. Maybe life satisfaction is a part of life quality and thus so fundamental that job changes do not effect it. Or the intervention made the careerist/adaptables find ways to keep up their life satisfaction but it was not efficient enough to improve the situation for the reconsiderers/bewildereds. Should it as first suggested be fundamental and as such part of personality profile, it may even be considered as a predictive factor for how well changes in employment is handled of the elderly, i.e. to be an asset or a liability respectively.

The results are best understood against a theoretical model of life span psychology. Such a frame of reference focuses on how life experiences structure the personality but also how the handling of crucial life events accumulate experiences as coping strategies. Such a model has previously been presented by Hagberg (1990) and tested both for prediction of life satisfaction (Hagberg 1992) and survival (Hagberg 1993) The model is multifactorial and relates life span changes, personality, coping-strategies, locus of control and life satisfaction to each other. The model also provides for interventions at different levels either directly on personality structures or as support of coping strategies. In the present study the life span changes are a combination of ageing and changing work conditions, which are dealt with by the individual supported by counselling. Since the outcome in terms of life satisfaction is stable and the greatest variability is found in personality characteristics the most likely interpretation is that the outcome is dependent on the personality structure. The rather modest intervention seems to have worked in the area of coping and thus for some contributed to a satisfying handling of changing work conditions. For others the intervention has not improved life satisfaction but on the other hand there has not been a further decrease either.

The strongest differentiating power seems to come from the locus of control variables. In the model they are denoted as interior and exterior mood of adaption and adjustment respectively. The satisfied careerists and the adaptables all have an internal locus of control belief in contrast to the others. Locus of control is of central importance for both perception of work condition as well as for ageing changes and life satisfaction. Regarding the relation I/E control and work condition, not much research has been done up to now (Hoff & Hohner 1986). In relation to I/E beliefs work condition analysis has focused on perceived restrictiveness. And the less restriction that is perceived the more likely it is that the individual has an internal control belief.

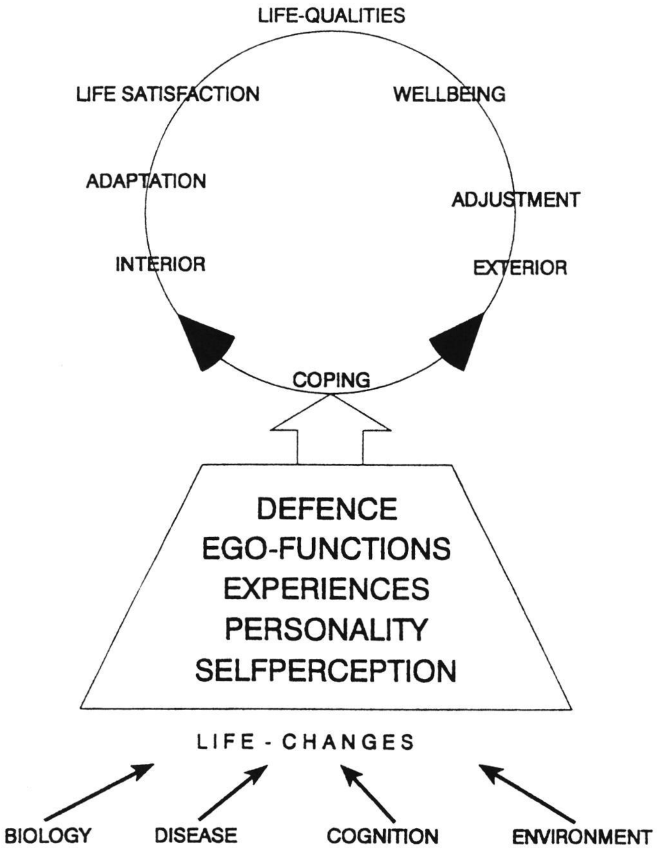

Figure 1: The coping model

High occupational level, high professional level, employees in management positions, professionals with high levels of training all score higher on internal control beliefs than none-supervisory and less qualified employees.

Which way the interaction goes between handling job conditions and personality is still unclear. Kohn and Scholler (1982) examined the interaction over time in a longitudinal study and concluded that job facilitating self determination leads to an autonomous orientation, while jobs that are restrictive tend to promote a conformistic attitude. But at the same time an autonomous attitude often leads to jobs that offer greater possibilities for occupational self-fulfilment. So given enough flexibility and dynamics in the job market, an internal control belief may facilitate a job career through interaction between personality and active job choice which confirms the internal control belief and at the same time develops work condition toward an autonomous position.

Such an argumentation is also supported by results from studies on job satisfaction, career success, job performance and job involvement, which all are qualities that are found to go together with internal locus of control beliefs (Hoff & Hohner 1986). Of course, the matter becomes crucial with increasing age. For some the actual influence decreases with age, for some it increases, depending upon how the career develops. For a person with internal control beliefs a career with increased factual influence probably leads to a confirmation of self-image and makes it easier to maintain a high life satisfaction with increasing age. This might be the situation in the first and second group, the careerists and the adaptables. Among the adaptables it is complemented with efficient coping strategies to handle changes in a way that he considers congruent with own control.

The last two groups, the reconsiderers and the bewildereds, show low life satisfaction before and after the study period and changes in job condition did not seem to affect the experienced life satisfaction. They all had an external locus of control belief. Knowing the relative stability in personality disposition with increasing age, changes in control beliefs were not to be expected. Rather it seems as the external control belief does not agree with the kind of middle level management that they are engaged in. The interventions were not intensive enough to change the working condition to a situation more compatible with their control beliefs. Taken together with the conclusions based on the coping model internal control beliefs and coping strategies together with the initial life satisfaction seem to be the single most important factors for a positive outcome of job changes for this group of middle management employees with an age between 45 and 60 years.

Acknowledgement
The authors would like to thank psychologist A.-S. Ahlberg who carried out the interviews and psychological tests.

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Middle-aged and elderly women's work and health - a model

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Abstract
This study is part of a larger ongoing research project: Winners and losers, a study of the work environment of middle-aged and elderly women. Women's health, well-being and opportunity to use their resources at the Swedish labour market are focused. The project is funded by the Swedish Work Environment Fund.
Structured personal interviews with 175 women in six different female dominated occupations are completed and analysed. The material is a non-proportional stratified sampling with simple random sampling within each stratum. Selected occupations are class-teacher, nurse, home help carer, shop assistant, secretary and self-employed persons.
The literature review indicates that a number of variables may contribute to women's health and well-being at the working-place as well as at home. The bivariate analyses mainly supported the hypotheses, even though clear differences between occupations are shown.
A causal model (SYSTAT/EZPATH) was tested relating the following latent variables: perceived work load, personal characteristics and health. The model was examined using the present empirical data with an acceptable fit ($\chi^2 = 65.04$; df = 51 p=.089). The goodness-of-fit index (GFI) and the adjusted GFI (AGFI) of the model is high (.940 and .909). The mechanisms for attrition of female workers from the labour market is discussed in terms of the model.

Introduction
Who are the winners or losers among the middle-aged and elderly women in the labour market in Sweden?
The presentation is part of a larger ongoing research project: Winners and losers, a study of the work environment of middle-aged and elderly women. Special emphasis is on women's health, well-being and opportunity to use their resources.
The study was carried out in four parts. 1) A structural analysis built upon official Swedish statistics and specially ordered statistics on the whole work force from the National Board of Statistics. 2) A survey (personal interviews) of 175 women (45+) in six female dominated occupations. 3) A survey (depth interviews) of 20 women from the same population a year after the first interview. 4) An intervention program with emphasis on self image, communication and perception.
The project is funded by the Swedish Work Environment Fund.

Aim

Since we know comparatively little about the elderly women at the Swedish labour market, the main research question is if it is possible for women to grow old (without stagnation) in their present occupation?

Research questions for the project are:

- In what occupations are they?
- How do they move between occupations?
- What is the relation between the older groups (55 to 64 years) and other female groups at the labour market?
- What is their work environment like?
- How are their health and well-being at different work sites and what are their possibilities to use their different resources?

In this presentation of the study the emphasis is on the *last* question.

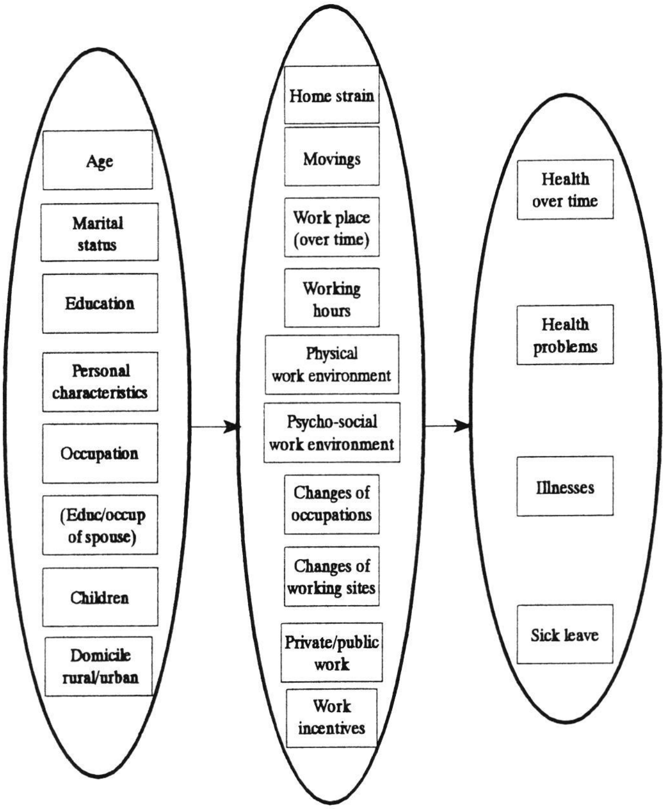


Figure 1. Interview spheres (ovals) and a hypothetical model for middle-aged and elderly women's work and health. The interview form includes more than 300 variables.

Definitions

There is no date after which a member of society becomes middle-aged or old and there will be no clear consensus on it. Still we define *middle-aged* and *elderly* in the work force chronologically as 45-54 and 55-64. The motives are mainly the criteria of the Swedish National Social Insurance Board.

Hypotheses and instrument

The starting point is that there are different interrelations between specific variable spheres (ovals in figure 1). For the purpose of clearness of the figure no arrows are marked out. The second starting point is that age, social group, occupation, personal characteristics etc. (i.e. the total demographic variables to the left in the figure) cause a total work load (the box in between) that affects the health and well-being of the women.

Method in this part of the study

Personal interviews

Structured personal interviews with 175 women in six different female dominated occupations were completed and analysed. The selected occupations were class-teacher (form master), nurse, home care provider, shop assistant, secretary and self-employed persons. The interviewees represent 115 different places of work.

Sample

The material consists of a non-proportional stratified sampling with simple random sampling within each stratum. The strata were the location of the working site (58 urban and 62 rural), occupation and age group (in 5-year interval; 45-49, 50-54, 55-59, 60-64 years).

Results

The interviewees do not differ in any way of vital importance from other middle-aged or elderly Swedish women regarding demographic facts like present marital status (66% married or living together and 15% divorced), number of children (less than two), education (fairly low compared to younger females and domicile (less rural than urban).

Self image and attitude to work

In a cluster analysis two basically different groups were found with quite different ways of looking upon their work. One sees the work as 'non-stimulating' and one sees the work as 'stimulating'. These two groups coincided with the way the interviewees looked upon themselves.

Characteristic for the 'high stimula' group, the elderly women with a stimulating work - and this is 65 percent of the interviewed women - is the involvement. Happiness and satisfaction are the most important things in their work and also development and change. At the bottom of the list are economical independence and salary, which may be one aspect for understanding women's low interests in planning for retirement (Lannerheim, 1993:30-33). These women see themselves as harmonious, active and independent with a positive view of life (figure 2).

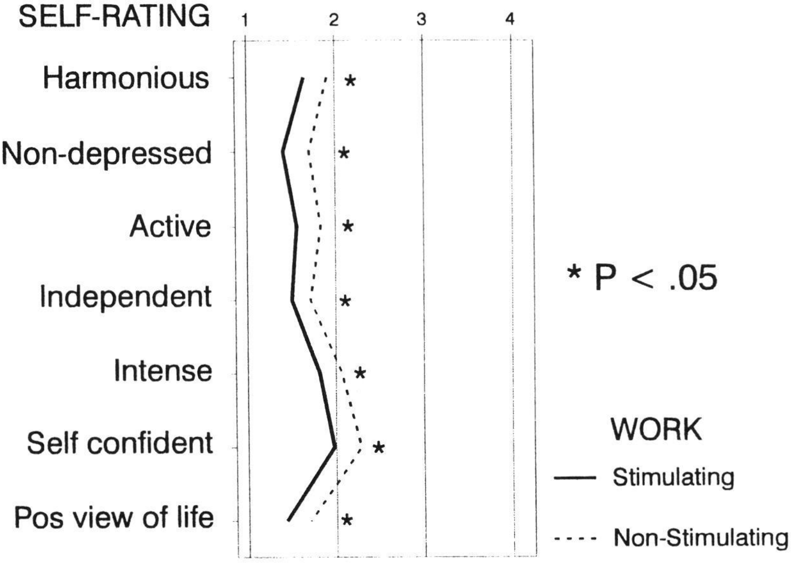


Figure 2. Self-rating scale on certain personal attributes

The women in the low stimulation workgroup - 35 percent of the interviewed women - are working mainly for the salary. They often have a bad self image and also a lack of pride in the work that they do. They are less independent and more depressed than other women (figure 2).

Health, illness and sick leave

The ip's subjective states of healths have been estimated by themselves in different variables. We found a trend against lower experienced health (physical as well as mental) up to 60 years, measured over life-time. After that the trend is broken. This is very likely due to early retirement pension among those younger than sixty years. Women with a very bad health leave the work force before or at this time (Hoog & Stattin, 1992).

The class teachers show the highest level of health problems but not a high level of sick leave.

Concerning illnesses that clearly affect the women's life styles 30 percent mean that they to some extent suffer from those, though often helped by medical treatment. Therefore some of the elderlies who have illnesses that clearly affect their life styles have not had one day's sick leave. Another 13 percent state that they have some kind of illness that very much affects their way of living. Not surprisingly the biggest problem is skeleton and muscle pain in the back of the neck, the knee, the back and the joints.

113 persons of 175 have been sick-listed at least once during the past year. One third of them have less than four days off for health reasons and 3% were full-time off during the whole year. Of the sick-listed, 15 percent state that the actual work is the cause of the sick-listing. It may deal with physical or psychological strain in work, monotony or high work pace.

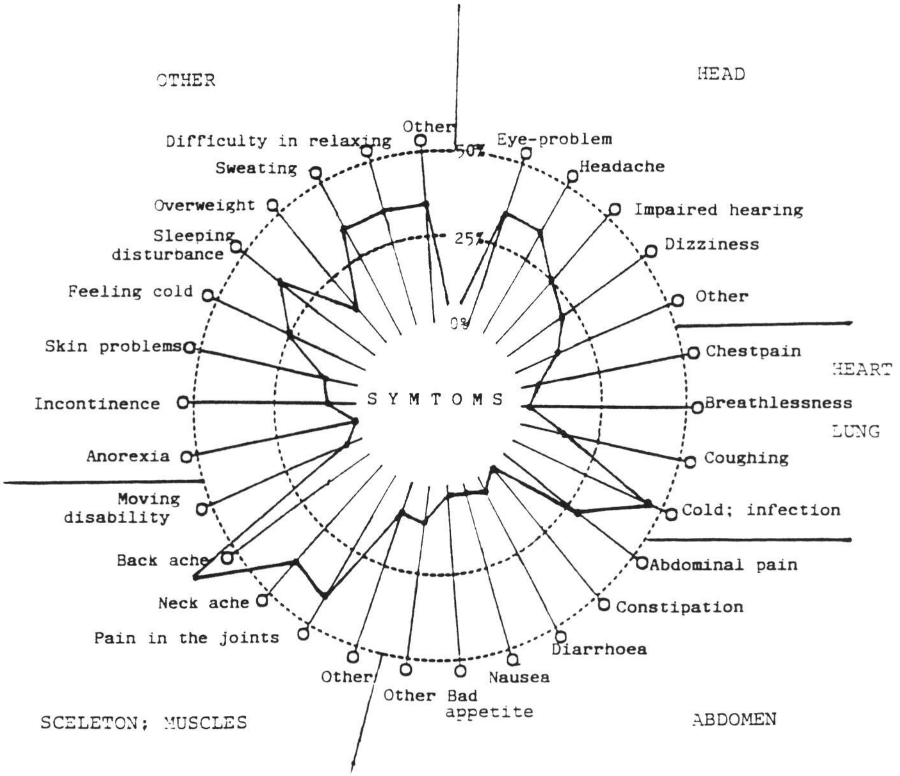


Figure 3. State of health. 29 symptoms in the total population (n=175). Inner and outer circles represent 25% and 50% respectively

In this survey the psycho-social work environment is particularly observed. Only three percent state psycho-social factors at work as the reason for sick-listing, but there are large differences between the professional groups.

Nurses and secretaries show the highest level of well-being while teachers show most signs of being burnt out. Involvement in work is important for well-being, but for teachers the big involvement changes to feelings of being inadequate.

We also asked the ip's if they had felt the need to stay home from work without being physically sick. Of the 175 interviewed women another 28 percent wanted to call in sick some day due to stressful work and 13 percent due to psycho-social factors in work and 18 percent due to difficulties with adjusting work at the work place and at home. The latter is recognized among the women who are looking after ill or older relatives.

In relation to self-reported total stress at work (10 variables; see fig. 1 the boxes in between) we found class teachers at the highest level (m=3.73), followed by nurses (m=3.01). At the lowest level are secretaries (m= 2.03) and self-employed persons (m=2.20). Mean for the entire population is 2.79.

A 3-way ANOVA shows that the total level of health problems contributes to the level of stress and if one has work that is seen as high or low stimulating. There is e.g. a significant difference between the occupations class-teachers and nurses among those who find their work stimulating. The teachers, who show a very high level of stress and at the same time have a stimulating work, they also have many health problems. This is a typical sign of being burnt out.

Teachers with a low stress level also have more health problems than nurses at any stress level. No difference is however found between the two occupations among the women who see their work as not stimulating. Independent of stress nurses with a non-stimulating work have more health problems than those with a stimulating work, which is expected.

Model

The literature review indicates that a number of variables may contribute to individual health and well-being at the working-place as well as at home (e.g., Doering et al., 1983; Sauter et al., 1989; Karasek & Theorell, 1990; Lannerheim, 1993). The bivariate analyses mainly supported individual relationships within as well as between variables and clusters in the hypothetical model (figure 1), even though clear differences between occupations are shown. This led to a multivariate analysis after a certain cultivation of the variables: Variables with a high intercorrelation were brought together (combined) within each measured sphere. The multivariate analysis then was made according to the hypothetical model with a - for the user - simplified LISREL technique (SYSTAT/Ezpath. Steiger, 1989).

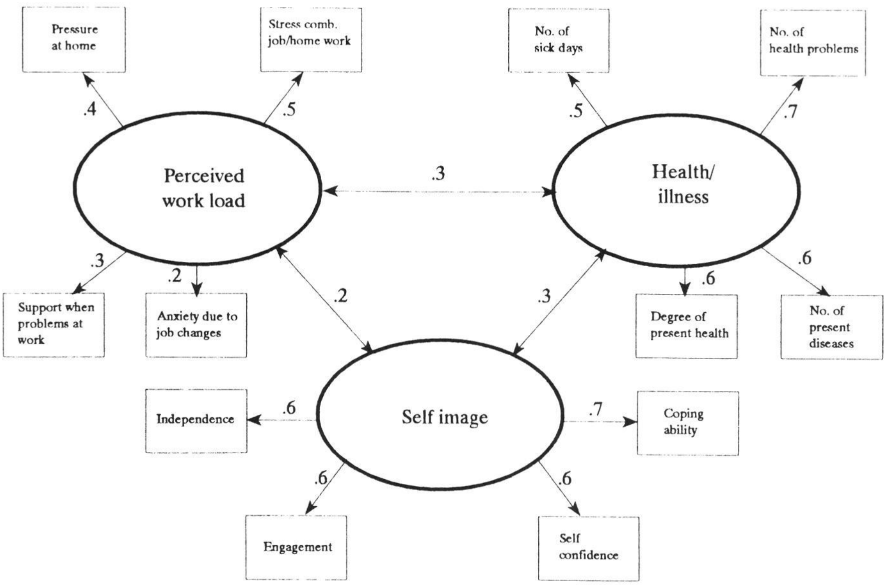
The model (SYSTAT/Ezpath) was tested relating the three latent variables perceived work load, personal characteristics and health as defined by the following manifest variables.

Perceived work load as measured by levels of:
- Stress at least once a week due to home strain (family/relatives)
- Stress in combining job situation with family and home work
- Help and support by problems at one's job
- Anxiety for changes at one's job such as reorganization, new job content.

Self image as measured by the level of presence of the following attributes:
- Independence
- Engagement/Intensity

- Self confidence
- Coping ability

Health/illness as measured by stated:
- General health just now
- Number of illnesses just now
- Number of health problems during the last twelve months.
- Number of sick days during the last twelve months.



(χ^2 = 65.04; df = 51; p = .089; GFI = .940; AGFI = .909)

Figure 4. Middle-aged and elderly women's work and health. A preliminary model

The model was examined using the present empirical data with an acceptable fit (χ^2 = 65.04; df = 51; p = .089). The chi-square was not significant which means that the model did fit the data and that the model must be accepted. The goodness-of-fit index (GFI) and the adjusted GFI (AGFI) of the model is high (.940 and .909) indicating that a large amount of covariance and variance was accounted for.

Conclusion and discussion

The model shows clear interrelations between women's self images, the degree of total reported work load (at the working site as well as at home) and women's health. The condition for this is that the latent variables are defined as presented above.

Instead of causal relationships between the latent variables as hypothezised (fig 1) interrelations were found. In spite of this the model must be accepted seeing that it is not designed for a time perspective but for the present situation with reference to the factors which decide how the women look upon their work, upon themselves and their well-being.

Data support the conclusion that pressure at home and problems in adjusting the home situation with the job are of greater importance than was expected. After all these women do not have small children any more, thus their work load could be assumed to be lower than before. The previously made bivariate analysis showed however that it is not at all women with children living at home who have these types of problems, but rather women living alone often with caring responsibility for older relatives or women with a very high stress level at their jobs.

In the model the work factors are shown to be less important to middle-aged and elderly women than home strain and problems in adjusting the home situation with the job. The work factors that have the highest loadings are level of help and support when there are problems at work and also anxiety due to changes at one's job such as reorganization and new job content. We know that a weak social support often interrelates with a weak health, but what is the meaning of anxiety about job changes? It could be interpreted as fear of losing control of one's job or fear of losing the job, which in the extension means that control is of vital importance.

The latent variable self image is defined by the attributes self confidence, independence, engagement (intensity) and coping ability. Other personal characteristics as level of activity and view of life did not contribute to an even better model.

Bivariate analysis supports the conclusion that women with the apprehension that they have only a low degree of the personal characteristics as in the model also have little control of their work situation as for decision making and time utilization. Even if these last variables are not included in the model, these findings can indicate that women who value themselves low, they dare not get control even if it would be possible.

Some of the health variables could be looked upon the same way as Honkasalo (1989) sees it. She means that physical symptoms are often used by women to communicate when they are unsatisfied with conditions in their private lives or in their working situation. Thus the health problems are not to be seen as diseases but rather inconveniences.

Karasek and Theorell show that a high work load, little control of one's work and a weak social support cause different types of psychosomatic problems (1990). They do not include self image however. In this study some of the symptoms could be seen as psychosomatic e.g. headache and abdominal pain (fig. 3), but to what extent could symptoms as back ache and neck ache be seen as such? These symtoms cause a lot of early retirement pensions among elderly women in Sweden.

In this preliminary model interrelations were found instead of causal relationships. Next step in the development of the model will be to identify causality. Probably the manifest variables may be modified or selected once more. A problem is that the material (n=175) needs to be larger to be able to bring further manifest variables to the model.

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Aging and ergonomics: the challenges of individual differences and environmental change

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Abstract
Aging is universal but not uniform. Genetic differences combine with unique life experiences resulting in differential exposures to disease, environmental trauma, and variations in the built environment. Heterogeneity, not homogeneity characterizes the process of aging as well as its results, as observed in persons or groups defined by the calendar as old or elderly. Heterogeneity means that specific applications of ergonomics for the elderly will require full application of the dynamic systems concept of human factors theory, i.e., task modification or the selection, training, or adaptation of the person or some combination of both to achieve a desired systems outcome. Moreover, because aging itself means change, the design of environments and equipment used over the lifespan should include the potential for changing requirements associated with aging. Designs based on developmental principles - e.g., systems that have the potential for stimulation and challenge as well as accommodation to human capabilities - have the potential for changing conventional concepts of human aging. Finally, secular changes in the complexity of the built and technical environment requires that system design helps prepare users for further changes, not simply for adaptation to the current system. These ideas are discussed in relation to criteria for human factors research on aging, manpower development and pragmatics of design.

Introduction
Mr. Chairman, ladies and gentlemen. I want to thank Professor Jan Moraal and the members of the program committee for inviting me to participate in this 10th anniversary meeting of the Europe Chapter of the Human Factors and Ergonomics Society. I am especially pleased that the theme of the meeting is human factors and aging. I realize that aging is not a popular topic among most ergonomists nor laymen, but it is of relevance to all of us. I am convinced that there is not a parent in this room who would want his or her teenage daughter go on a date with a boy who had a reputation as bad as aging or old age. One reason for aging´s bad reputation is the common association between disease and disability and old age - like the gentleman in the cartoon who says "If I knew I would live this long, I would have taken better care of myself." In fact, the bad reputation of aging has its beginnings in early development and poor parental training is largely at fault. One sees this reflected in two children's cartoons about aging. In one, Dennis the Menace asks his father's friend, "...and what age are you in the middle of?" In a second, the

little boy asks his grandmother, "...if I'm only young once, then how many chances do I have to be old?" These ingenuous remarks suggest that we parents are not doing such a good job educating our young about aging. In an ideal world we would pass through our lives being as smart and wise as the old man who in response to the question, "How old are you?" said: "What age do you mean, my anatomic, physiologic, psychologic, moral,...or chronologic?" The old man is smart because he can make all those distinctions; he is wise because he put chronologic age at the end of his "list" of ages. The remark of the old man highlights a major theme in this talk - namely that there is no single identifiable group, "the elderly." The cumulative effects of individual differences in genetic makeup combined with a lifetime of unique experiences combined with various exposures to illness and environmental stressors mean that coevals by the calendar will be, most likely, less alike one another in old age than earlier in life.

Human Factors and aging over the past decade

The tenth anniversary of the Europe Chapter of the Human Factors and Ergonomics Society roughly corresponds to some significant advances in the speciality area of human factors and aging. For starters, consider the Human Factors and Ergonomics Society itself. In February, 1981, the first special edition of Human Factors was published with seven articles. Almost all of them were theoretical essays or literature reviews. I was the editor of that special issue which I dedicated to the memory of a great pioneer in ergonomics and in human factors and aging, Dr. Ross McFarland. Fifty years ago, McFarland published the "Older worker in Industry." Almost all of the articles in that special issue were solicited by McFarland or myself.

In October, 1990, the second special issue of *Human Factors* was published under the editorship of Dr. Sara Czaja. The advances in human factors and aging over the decade were everywhere evident - enough papers that a sister journal, the *International Journal of Industrial Ergonomics* was persuaded to take the overflow. In contrast to the first special issue, there were several empirical papers in the special issue and its overflow, including a report by Clark, Czaja and Weber (1990) of the advances in the task analyses of everyday activities, such as bathing, meal preparation, shopping etc. The overview article by Smith (1990) was able to report and comment on a much more dense and active decade than was possible by Fozard (1981) in the first special issue. In addition to the special issue, an overview of the potential uses of research and practice in human factors and ergonomics for an aging population was published in the Society's Technical Bulletin by Fozard and Fisk (1988).

Another important development in the Society was the steady growth of the Technical Group on Aging, founded in the late 1970s through the efforts of Arnold M. Small. Dr. Small served as the first chairman of the group, edited the Newsletter and recruited members almost single-handedly for a period of years. The second chair was Dr. James Baker, followed by myself for a period of four years. During my tenure as chair of the group, Drs Small and David Smith, and a few others did a lot of missionary work. By the time I served my last year as chair, the Technical

Group had a good enough infrastructure that there are now annual elections of officers, a very lively newsletter and vigorous planning for the annual scientific program. As in the case of the second special issue of Human Factors, the annual programs have included progressively more empirical papers from a variety of sources. Members of the Technical Group on Aging are organizing a session on aging for the International Ergonomics Association to be held in Canada in 1994.

In the United States another significant milestone was the 1990 publication of the National Research Council report "Human Factors Research Needs for an Aging Population" edited by Sara Czaja. The National Academy of Science Committee on Human Factors identified a panel that represented members of the Human Factors and Ergonomics Society as well as experts from other disciplines. That document, along with the 1985 Congressional Office of Technology Report on Technology and Aging did much to alert government and other groups interested in aging to the possibilities of using human factors knowledge and skills to promote and maintain the independence of older persons.

David Smith (1990) identified several other significant events, including the convening of the conference on the older driver sponsored jointly by the Department of Transportation and The National Institute on Aging. One outcome of the conference was the publication of another special issue of *Human Factors* on that topic. He cited the publication of the first chapter on human factors and aging by Charness and Bosman (1990) in the third edition of the Handbook of the Psychology of Aging.

A major problem in developing the research side of human factors and aging is support for research projects - particularly in a field where the predominant support has been from the military and defense communities. The decision of the National Institute on Aging to begin supporting human factors research and the assigning of staff to carry it forward was an important development. Although the budget available for the research is very small by Department of Defense Standards, and there is considerable difficulty in getting the peer-review machinery in place at the National Institutes of Health, there has already been a substantial number of projects initiated with this support. When Chapanis (1974) argued that human factors specialists needed to diversify their interests into nonmilitary problems such as those associated with aging, he was truly in advance of his time. Almost twenty years later in 1993, the need is obvious and current.

In Europe there has also been a substantial increase in interest in human factors research and practice towards the elderly. For example, design activities have been strong in Britain, Sweden, and research on aging and work has been strong in Finland and the Netherlands. One of the most important recent activities in the Netherlands has been the development of "Gerontechnology." The conference and publication of the book on the topic sponsored by the Eindhoven University of Technology has been a major stimulus for interest in the use of technology by and for the elderly (Bouma and Graafmans, 1992) Gerontechnology and human factors as applied to aging overlap in many ways but there are also important differences. They both use the lifespan developmental view mentioned above as a theoretical framework and they both are concerned with age changes in the interactions of people and equipment and products. Gerontechnology differs from human factors inasmuch as it does not include changing person/environment interactions by training, counselling or selection of people, except for the technology that might be involved in such efforts. Also gerontechnology is directly concerned with the impact that secular changes in technology have on the adaptation of older persons to those changes.

I would like to spend the remaining time discussing the future directions of human factors and ergonomics as they apply to aging and the aged. There are four areas of concern: the conceptual basis for future work, the research and knowledge base, the development of manpower, and the pragmatics of design and evaluation.

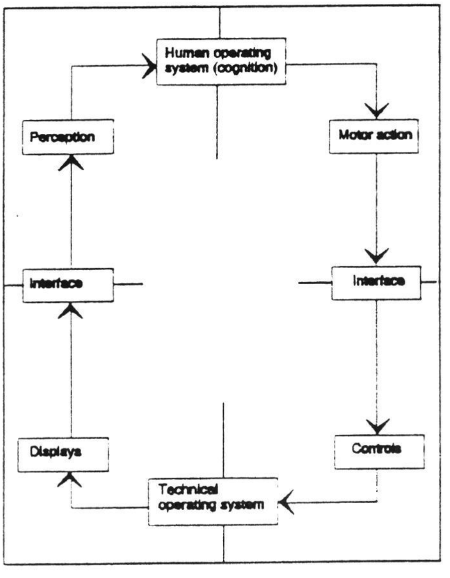
Conceptual basis for future work

Smith (1990) identified two broad models that have guided human factors and ergonomics thinking with respect to aging. The first, articulated by Faletti (1984) and Lawton and Nahemow (1973) focuses on physical and psychological decline with aging; the decline is seen as a person-environment problem. The role of human factors is to improve the match between human capabilities and demands of the environments - to optimize the fit between the human operator and the equipment or environment in which the person functions. Task analyses such as those initiated by Faletti (1984) and further developed by Czaja and her colleagues (Clark, Czaja and Weber, 1990). As human capabilities with respect to sensory, cognitive and mobility functions decline, tasks and environments of the person are adjusted to enable the person to continue functioning.

The second, articulated by Fozard and Popkin (1978) and Fozard (1981) emphasizes the developmental aspects of aging. Smith (1990) summarized their main ideas: "...the ideal approach to design for the elderly would (a) accommodate aspects of constancy and growth as well as decline; (b) be sensitive to social and psychological needs as well as performance needs; (c) because both people and environments change, acknowledge the temporary nature of generalizations about aging." (p.511) Training, needs assessments and counselling are additional useful methods of study and intervention to task the task analytic approach used by Faletti.

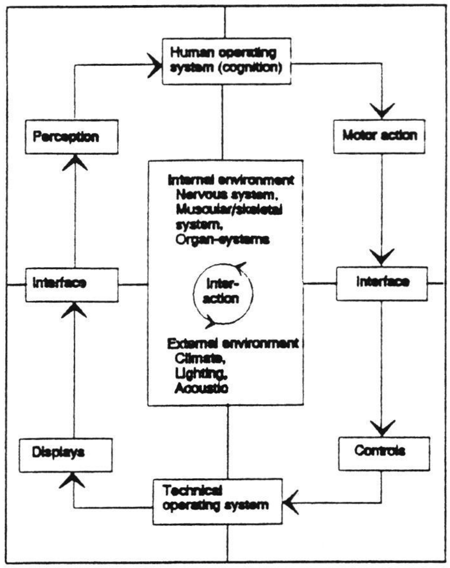
Both of these views share the central philosophy of human factors - a systems approach toward aging. The philosophy is well articulated by L.E. Morehouse(1958): "The ultimate aim of each human factors effort is toward the optimal utilization of human and machine capabilities to achieve the highest degree of effectiveness of the total system." With respect to research on human factors and aging, Robin Barr (unpublished) put it well: "The promise of human factors research ...is contained in the control over performance that can be achieved by altering the dynamic of the operator-task environment." The implication of this philosophy for human factors practice as well as research and aging is that aging itself cannot be defined independently of the environment - age grading of human abilities and functioning only has meaning in reference to environmental challenges and supports. It is largely for this reason that the NRC report on Human Factors for an Aging Population (1990) identified as the highest research priority the need for "good distributional data on tasks, problems and abilities and to perform detailed task analysis where the benefit is likely to be the greatest..." (p.66).

The relationship between the developmental view of human factors and aging and the systems approach is illustrated in the next three slides.

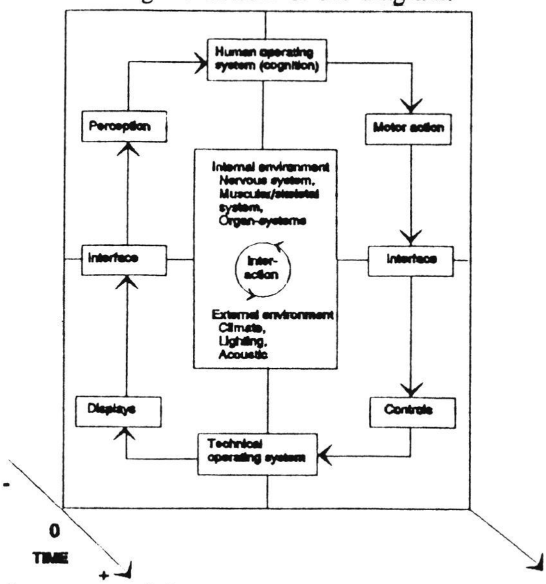


At any point in time the interaction between a person and her or his environment may be characterized by the two dimensional figure familiar to human factors experts. Starting on the center left and going up, information is received from the environment-perception. Events within the person results in actions which may adjust or modify controls of the technical operating system which may be a vehicle, a device at work, or a housing system.

In the next slide, the center box spanning the interface line in this version of the standard systems diagram is particularly important because it identifies the environmental considerations - both internal and external - that must be taken into account in human factors applications involving age differences among persons. Age associated differences in sensitivity to the visual, acoustic and thermal environment as well as individual differences in strength, cognitive abilities, etc., are the main things that determine whether it is necessary to age-adjust the relationship between the human and technical operating system. Whether the contrast characteristics of a visual display for a particular application is optimal for both a young and old adult may depend on differences in sensitivity to ambient light conditions and many other conditions. Most human factors research related to aging deals with these problems.



The developmental view of human factors also adds a dynamic aspect to the systems concept as indicated by Smith (1990). This is illustrated in the next slide by the time dimension or "time track" along the bottom of the diagram.

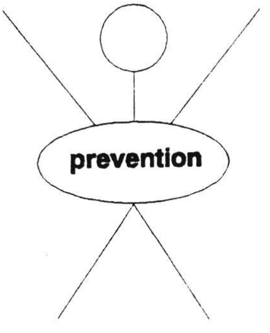


The "0" denotes the present, "-" the past and " + " the future. Because both technology and the environment change over time at the same time a person is aging, personal aging and the time period during which a person ages are interdependent.

Technology introduced at the present time (0 on the time axis) may affect how young and old persons adapt to it (- to 0 on the time axis) and it may alter the course of aging itself (0 to + on the time axis.

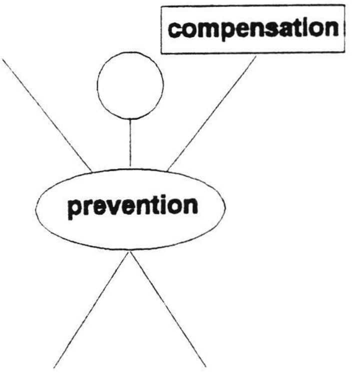
Perhaps the most interesting implication of the developmental view of human factors is that ergonomic interventions should emphasize adaptability of architecture and products as a design principle. In housing for example, the interface between equipment and appliances and their user may change over time even though the function of the equipment/appliance does not. Over time the requirements for space utilization may also change either because of age changes in the needs of the occupants or because of the desire to accommodate to newly introduced technology or products. The adaptability principle is now reflected in changes in form, e.g., movable interior walls.

The developmental view of human factors and aging outlined above suggest five ways in which human factors and ergonomics can address aging. These are illustrated on the next 5 slides.



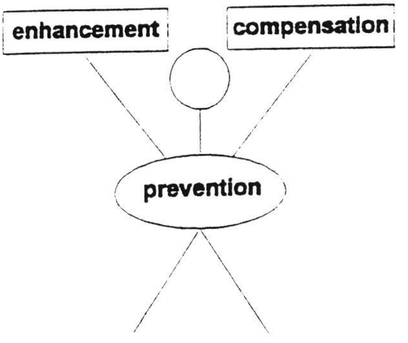
At the center of the diagram is "prevention." Many "problems" of old age are modifiable through long-range, nonmedical interventions involving nutrition, physical activity, exposure to chronically dangerous environmental conditions such as auditory noise, changes in lifestyle regarding alcohol and tobacco consumption, etc. How can human factors address prevention? Using physical activity as an example, technology for monitoring ambulatory levels of activity in everyday situations, and the design of exercise and recreational equipment that is fun to use, i.e., has a high positive motivational quality, and the design of ambulatory monitoring or warning equipment for improper posture for specific tasks such as lifting and general posture to prevent or slow the development of kyphosis. Recently Pendergast and colleagues (1993) proposed age associated criteria for several aspects of aerobic and strength abilities for adequate functioning in old age. Using as a reference the level of a 20 year old, they recommend as a minimum level: 10% of aerobic capacity; 40% of peak anaerobic metabolic power and substained anaerobic effort; 40% for ability to sustain a muscular contraction and 40% for ability to generate a maximal force. These represent the first scientifically based effort I know of to establish minimal goals for lifetime fitness and provide a basis for devising fitness programs.

Another example comes from the study of age changes in hearing thresholds. The next slide shows ten year changes in hearing thresholds for very carefully screened men and women ranging in age from the 20s to the 80s at time of first testing. The slide shows that average change in hearing level per year for frequencies ranging from 250-8000 hz. The dramatic difference between men and women is tentatively attributed to differences in chronic exposure to environmental noise. Any person in a group who had any evidence of noise induced hearing loss based on audiogram evidence using Kryter´s (1974) criteria was eliminated from the analysis. Comparison of the men who had evidence of noise induced hearing loss with those whose data are shown in the slide, indicated that in addition to higher initial thresholds, the rate of hearing loss associated with aging was relatively greater. The use of technology to monitor levels of noise in ordinary settings and to help reduce exposure to noise over the lifespan could reduce the prevalence of impaired hearing in old age.

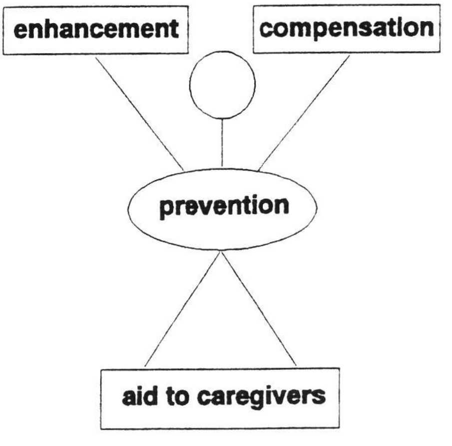


At the top right of the diagram is "compensation". The vast bulk of existing human factors efforts in aging focuses on this issue. Examples include improved lighting for various visual tasks, mobility aids, devices to improve ability to carry out ADLs, etc. In the case of lighting, a unique demonstration project in the Netherlands includes the assessments of home lighting as part of the evaluation of the clients, most of whom are elderly, and the visual aids prescribed for them. (Neve, Jorritsma and Kinds, 1993). Because lighting requirements are relatively task specific and there are such substantial individual differences in the visual abilities of older persons, I have recommended the increased use of flexible lighting systems in both work and home visual environments (Fozard and Popkin, 1978; Fozard, 1981). This recommendation has not been evaluated. The primacy of design of fixed lighting devices, e.g., floor, lamps, wall lamps and ceiling light systems is obvious to any visitor to a lighting shop, although recent developments of small intense light sources such as halogen lamps has been accompanied by more flexible lighting appliances.

Improved lighting of stairs, particularly in the home would also benefit the elderly inasmuch as most falls by them on stairs occur on the initial step of the flight of stairs, the step for which visual guidance is most important (Fozard, 1990). A simple design possibility would be to have a pressure activated switch on the floor near the top of the flight of stairs turn on a light that would illuminate the stairs for a short period of time while the person is traversing the steps. Lighting and step width and width are probably not the same for ascending and descending stairs.

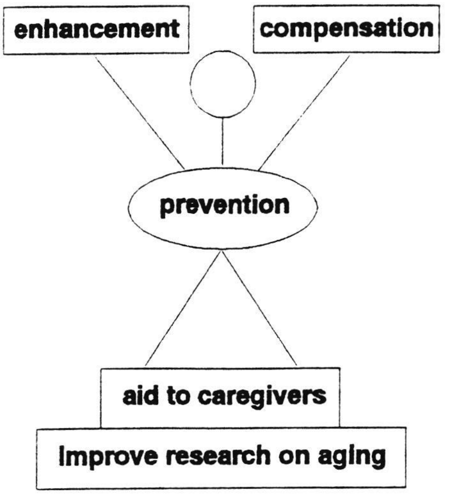


At the top left of the diagram is "enhancement". Aging brings with it challenges, which are addressed be compensation and prevention as described above. It also brings opportunities in the form of time for new social interactions and activities, time for new learning and leisure activities - self fulfilment. There has been virtually no attention paid to this aspect of aging by human factors and ergonomics. The exception is the design of adaptable housing to suit the differing needs of people during the life cycle of the family. The potential uses of technology for enhancement of activities is particularly intriguing.



What are some ways in which human factors and ergonomics can contribute to enhancement? One potential area is in user-friendly technology in communication to facilitate remote contacts with family and friends, to make new contacts and to participate in educational activities remotely. Another area is in the development of user-friendly computer systems for games, artistic and creative activities and learning through multimedia technology. The experiences as well as ages of potential users of technology vary with respect to the timing of introduction of technology and the user-friendliness of ergonomic design must include features that interest and motivate older as well as younger adults.

Toward the bottom of the diagram is "aid to caregivers". Ergonomic analyses and design of devices to lift and transfer people who cannot move themselves and devices that assist caregivers in providing assistive and medical care are included in this category. One of the most significant recent developments in home based medical care is the widespread use of complicated medical equipment by family and other nonprofessional caregivers, e.g., respirators, intravenous injection devices, monitoring equipment, etc. As many of you know the Human Factors Society is involved in the preparation of human factors guidelines for such equipment by the American Institute for Medical Instrumentation. Many of the developments designed to help individuals remember medication regimens currently undergoing ergonomic analyses as described in last month's Human Factors and Ergonomics Society Convention would be of equal use to caregivers.



On the very bottom of the diagram is "improve research on aging". As in the case of "aid to caregivers" the contribution of human factors to aging and the aged is indirect. It is a truism that technology is revolutionizing the scientific study of physiology, psychology and biology, and this is equally true for observational and interventive studies of aging. The impact is enormous both on data currently collected and in the reanalysis of archival information. An example of the former in the National Institute on Aging´s Baltimore Longitudinal Study of Aging is the study of differences in the dynamics of the strength training in young and old persons. An example of the latter was the use of electronic scanning devices that allowed twenty-eight years of historical data on pulmonary function to be digitalized and analyzed according to the same criteria for research quality pulmonary function data.

Research and knowledge base for Human Factors and aging

I would now like to discuss the research and knowledge base for human factors and ergonomics in relation to aging. As you are aware there is wide variation of opinion about the value of existing research for human factors and ergonomics applications. One of the founders of the field, Alphonse Chapanis has been one of the strongest critics. Yet, in the field of human factors and aging, one of the most influential publications is the National Research Council report entitled "Human Factors Research Needs for an Aging Population". Research that describes how old people spend their time heads the list of priorities for action according to that distinguished group. What should the future development of research be that meets the criticisms of Chapanis and promotes the scientifically based information the experts in our field need?

One possibility is to repeat the major human factors research studies adding age as a variable. The obvious difficulties with this approach include deciding on what the major studies are, and assuring that the data obtained are relevant to the needs of ergonomics practitioners. Another approach advocated in the report "Human Factors Research Needs for an Aging Population" is to do task analyses on the major classes of activities engaged in by the elderly and to recommend general design recommendations based on identified human limitations in strength, flexibility, mobility etc.

The task analysis approach is good because it identifies environmental demands in tasks which can be remedied by task redesign Additionally the redesign will facilitate performance by persons of all ages. The tedious and time consuming process of task analysis and the specificity of the results to particular activities discourage the widespread application of the method.

A third approach to the choice of research which encompasses the two just mentioned is based on a combination of the developmental approach to human factors and ergonomics activities and the criteria for "optimal performance engineering" proposed by Donald L. Fisher (1993). The centerpiece of both ideas is that the ideal human factors research activities and the reporting of research results would be in terms of performance of an "optimal system." This 'back to basics' concept is at the core of human factors theory as defined by Morehouse in 1958. In it, the mix of human and machine functions that yields optimal system performance is identified in such a way that rules are generated which predict how assignments of function to man and machine should change as system requirements change or in the case of aging what combination of mechanical and human components, if any, will yield equivalent system performance given a nonremedial age related change in the capacity of the human.

In my review of the human factors and ergonomics field in 1981 (Fozard, 1981) I proposed that wherever appropriate, human factors research utilize adaptive experimental approaches. The reason for that recommendation was to focus the research on the output of the man-machine system rather than the interaction between age and task difficulty. The literature available at the time was based on analysis of variance type research designs that almost invariably showed an interaction between task difficulty and age. The limitation of the literature was that the range of task difficulty represented in the study was unclear and the age range was inadequately sampled. The advantage of the adaptive experiment was that it would relate the variables studied directly to performance. For example, in a paced inspection task in which one was trying to identify the best combination of frequency and rate of presentation of target and distractor stimuli, one would first specify the desired system outcome, e.g., 80% correct identifications of the target with an acceptably low level of false positives, one would vary the rate and frequency of target presentation to identify the values of those parameters that yield the desired level of performance for persons who differ in age, sex, or some other characteristic.

Fisher's (1993) criteria for the best human factors research is based on optimal performance engineering. Fisher (1993) states that human factors design evolves through three stages - good, better, best. A good design may be the best, but because it is not arrived at without documentation or active consideration of other competing approaches, the best that can be said of it is that it is good. Better design is achieved when several solutions are proposed and evaluated in a way that incorporates proper controls. The best design is achieved when there is a theoretical basis for generating a large number of potential alternatives, and a basis for selecting and testing the most promising ones. The result is an optimal solution as defined by Morehouse (1958). Fisher then goes on to classify dozens of examples of research according to three categories of studies - empirical, theoretical and analytical. In each case he tried to show how the study examined approached the ideal of the optimal performance engineering. Accordingly, the idea that ties the examples of all three classes of research together - empirical, theoretical and analytical-- is that they approach the ideal of optimal performance engineering. Fisher provides an informal definition of optimal performance engineering "...a study can qualify as an instance of optimal performance engineering only if behavior is predicted or observed over the entire range of at least one design or environmental dimension." (p. 131) He then goes on to provide rules which govern what he calls the optimization process. He concludes with a spirited defense of the applicability and usability of human factors research if the research meets or approaches the criterion of optimal performance engineering. Because Fisher's criteria for quality research is solidly based on a systems approach, it seems to me to represent a good starting point for deciding the best strategies to use in generating research on human factors and aging. The task analysis approach of Faletti (1984) elaborated by Czaja and colleagues would qualify as approaching Fisher's criteria because it covers a wide range of situations. The adaptation of Fitt´s Law on the basis of age and sex proposed by Brogmus and colleagues (1989) is another. If suitably extended to include other variations, the work on age differences in sensitivity to stimulus response compatibility could be another.

Development of manpower

Who will and who should carry the torch for human factors and aging? The academic base for training scientists and practitioners in human factors and aging is very, very small. In the United States as in Europe, the traditional university base for training people in human factors is in departments of psychology or industrial engineering, and to a lesser extent, schools of architecture and design. In the United States, university programs that have promoted this area include, the Georgia Institute of Technology (Prof. Dan Fisk), the University of Southern California (Professors Smith, Small, Boyd), the University of Buffalo/University of Miami (Prof. Sara Czaja) Many other universities have graduated students with advanced degrees based on research related to human factors and aging including the University of Kansas, University of Dayton, University of south Dakota, University of Georgia and Virginia Polytechnic University. The development of research support mechanisms, largely through the NIA will increase the potential for training of graduate students in human factors and aging, a process that has already begun.

In the Netherlands, an ambitious and systematic effort to develop a University-wide educational and research program in gerontechnology has been started at the Eindhoven University of Technology. This includes the funding of doctoral level research projects. It is broader in scope than any others that I know of. You will hear more about this program in the presentation by Mr Graafmans.

For the foreseeable future the development of academic specialization in human factors and aging will have to proceed without a clear concept of the employment opportunities for the students who are being trained. This is also true for persons trained in schools of design and architecture. In a very important sense, the university is the best place for the development of human factors and aging, because it can respond to the demographic changes in the age distribution of the population at the same time respond to the changing needs for human factors training of young engineers and scientists. In contrast, industry has too short a time perspective at least for the present. Government agencies, being politically driven, also have a short term planning horizon even though such agencies may create the demand for human factors solutions for "problems of the elderly."

Pragmatics of design and evaluation

Just as aging and old age are not popular, neither is the idea of human factors for the elderly and the aging. A frequent observation by designers and marketers for products for the "mature market" is that a potential customer says - I don't need it because I'm sick and I'm not old. Conventional wisdom suggests that design should focus on needs that may or may not be age related as should marketing of products and technologically based services (Cullen and Moran, 1992).

One of the serious problems in developing human factors research in aging is the lack of input on the perceived needs of older persons and the use of them in evaluating products and services. The idea of a "mature consumers union" has been suggested by many persons. The difficulty with such a scheme is that products endorsed by such a group would suffer from association with the bad reputation of aging. Nevertheless the requirement for product evaluation with respect to ergonomics remains a major need for people of all ages. The special issue of *Applied Ergonomics* in the summer of 1993 provides many examples of the successful use of elderly persons in product evaluation in Sweden and the United Kingdom. I believe that the major ergonomic adjustments of products required for optimal use by the elderly will also benefit the younger adult so that product evaluation can be carried out in such a way that does not stigmatize the product.

Conclusions

Thank you for the opportunities to reflect on the current and future status of human factors and ergonomics as it applies to aging. In this presentation I reviewed the progress in this field over the ten years that the European chapter has been in existence. I recommended the continued use of the developmental or lifespan view of ergonomics as a basis for organizing efforts in this field. I suggested that we use Fisher's criteria for quality research as a basis for carrying out research on human factors and aging. I argued that universities should take the major risks inherent in developing manpower for efforts in human factors and aging. Finally, I recommended the use of the elderly in carrying out ergonomics evaluation of products.

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The workers' age and the adaptation of work situation to their capacities

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Preface
John Rendel de Jong died on the tenth of August 1994, while as ever engaged in his never diminishing efforts to develop and improve ergonomics & management. Among the things-to-do on his desk was the revision of the manuscript he presented at the Annual Scientific Meeting of the Europe Chapter in Soesterberg November 1993. The time to process the comments c.q. advices from the review committee was not granted to him anymore, reason why the members of the committee took the liberty to adapt his contribution into the chapter presented below, in the hope that it would have had his consent.

In honour and deep respect for his contributions to the field,

Karel Brookhuis, Secretary and editor
Clemens Weikert, President and editor
Jan Moraal, Director and editor

Introduction
The gradual decrease in the capacities of adult human beings in the course of their lifetime, has been the subject of numerous investigations since more than a hundred years. Many researchers have devoted much effort to unravel the course, nature and ground of the clearly diminishing performance. One example of such a relationship can be found in the performance of muscles. In Figure 1 the results of some of the studies by Quételet in Belgium in the sixties of the 19th century are summarized (Quételet, 1869). It is clear that shortly after adulthood is reached the maximum performance is found, after which it gradually diminishes.

Figure 2 is based on data that were collected by Wackwitz, while he investigated (at Philips Industries in Eindhoven) the relationship between the age of production workers and their performance on a number of tests (Wackwitz, 1946).
According to his findings, the gradual decrease in the investigated capacities was far from uniform; reaction time and memory appeared to decrease much more than, for instance, muscular strength and grasping time.

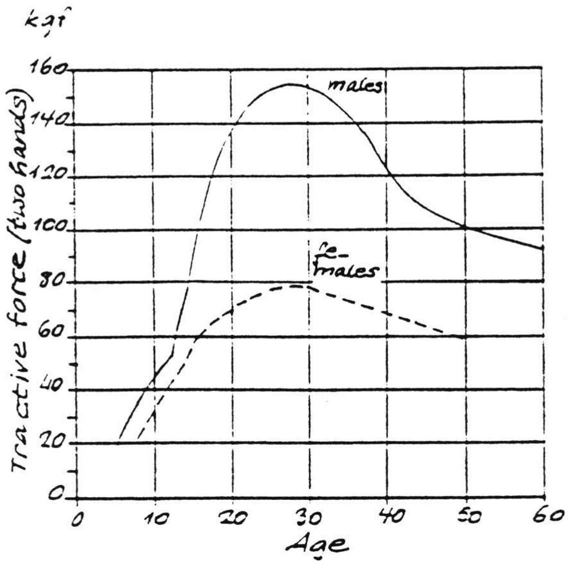

Figure 1: Human tractive force ('force rénale') as a function of age (adapted from A. Quételet, 1868)

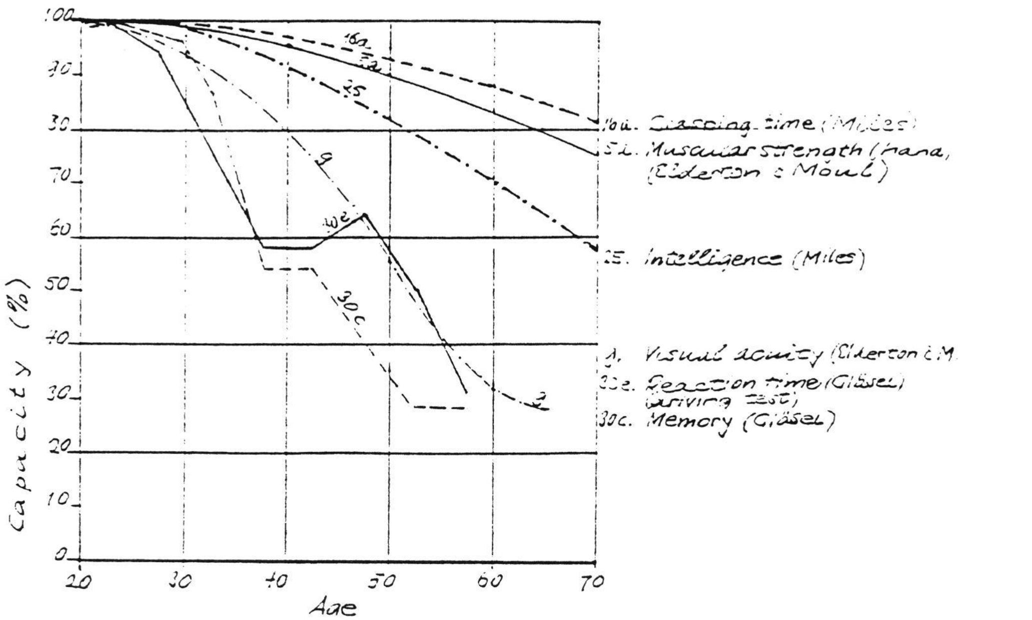

Figure 2: The relationship between age and several capabilities, in percentages, 100% = group maximum (adapted from Wackwitz, 1946)

Wackwitz' curves regarding the course of job performance in different departments of the factory (see Figure 3) bear a clear resemblance to the curves that concerned the muscle capacities. However, there is also a clear difference in so far that the maximum performances were attained about ten years later than the maximum capacities.
The extent to which job performance ultimately decreases, appears to depend on the nature of the task, such as illustrated in Figure 3.

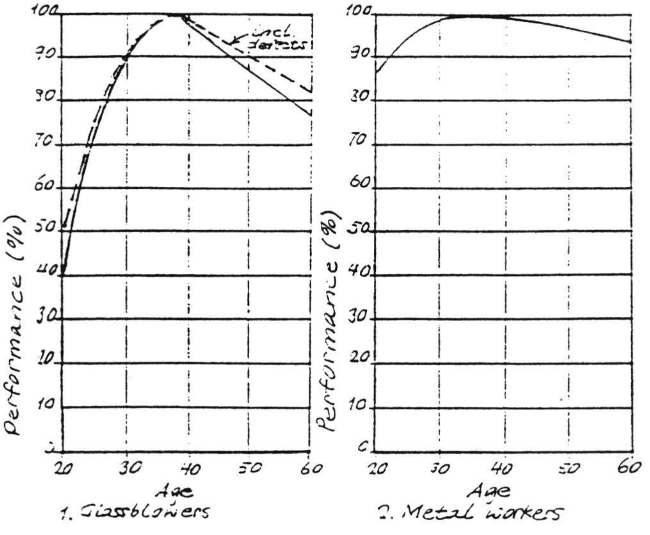

Figure 3: The relationship between age and job performance in two departments, in percentages, 100% = group maximum (adapted from Wackwitz, 1946)

It is a well known fact that individual differences are large. Figure 4 shows that the variance in production, the measure of job performance, was found by Wackwitz as large indeed.

A completely different picture emerges when the nett annual income of fully employed people is depicted as a function of age. Different from what is shown in Figure 3, there is no decrease in the course of the nett income for the employed older than 40 years. This micht be explained, at least in part, by phenomena shown in the course of the curves in Figure 6. There is a strong decrease in the number of employed per age class, starting at the middle-age class as a result of disablement and early retirement.

Other aging-related capacity-decreases that appear from research findings also differ widely. In the case of the dimensions of the body, the decreases are relatively small (Damon, Stoudt & McFarland, 1966). When the figures regarding the fifty years old are compared with those of the thirty years old, the decreases amount to 20 to 30 per cent in case of muscle strength and maximum oxygen consumption (Lehmann, 1962, Bink, 1962), and to more than 50 per cent in case of hearing, visual acuity and sensibility to odours (Rohmert & Rutenfranz, 1983, Verriest, 1979, Venstrom & Amoore, 1968) as shown in Figures 7, 8 and 9 respectively.

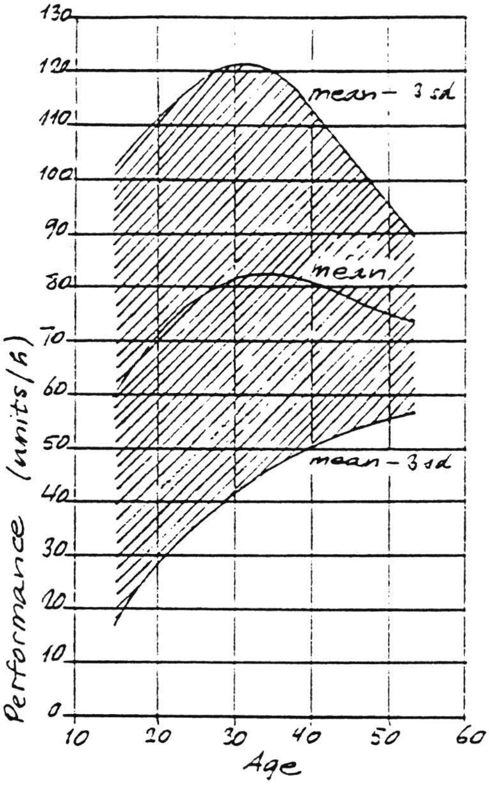

Figure 4: Variability in job performance of 3068 male and female production workers (at Philips Industries, adapted from Wackwitz, 1946)

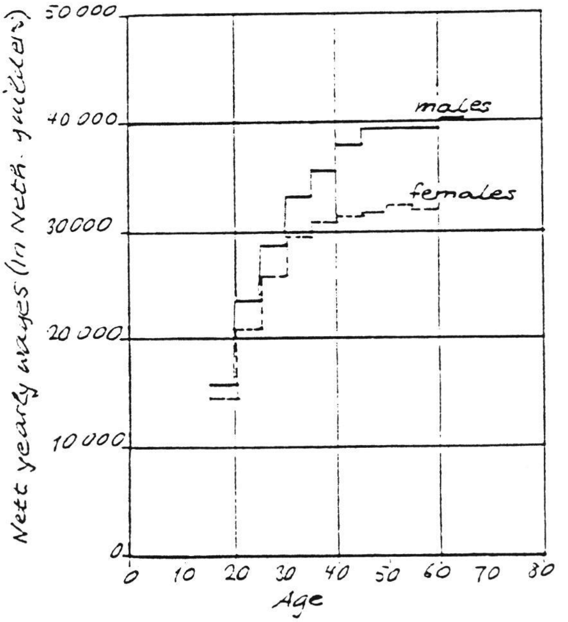

Figure 5: Nett annual earned incomes as a function of age by the full time employed in the Netherlands in 1990 (adapted from Statistisch Jaarboek 1993)

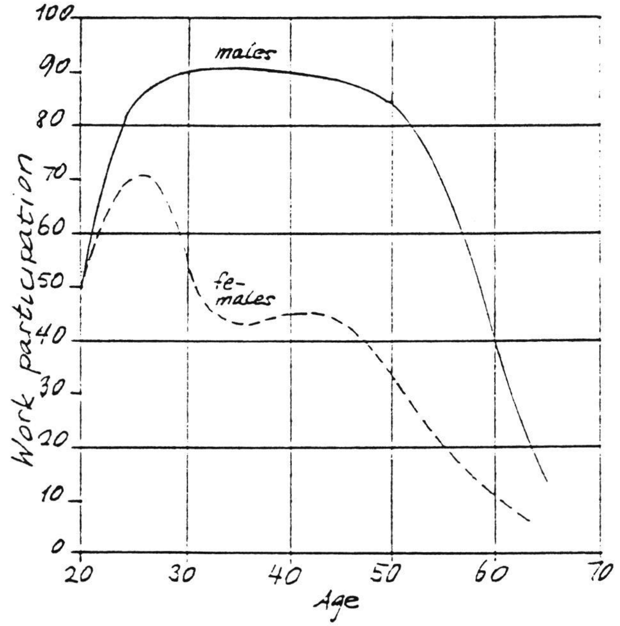

Figure 6: The distribution of percentage working population over age in the Netherlands in 1990 (adapted from Statistisch Jaarboek 1993)

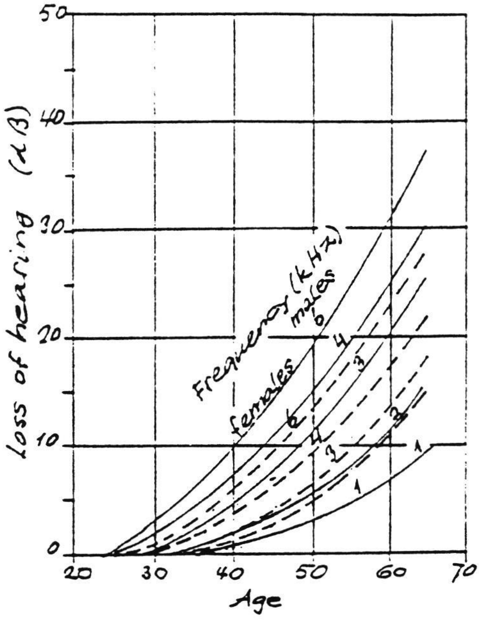

Figure 7: Average loss of hearing (adapted from Rohmert & Rutenfranz, 1983)

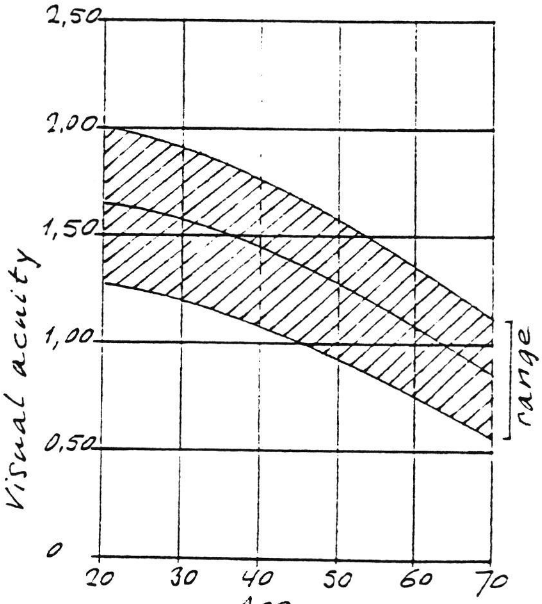

Figure 8: Average loss of visual acuity (adapted from Verriest, 1979)

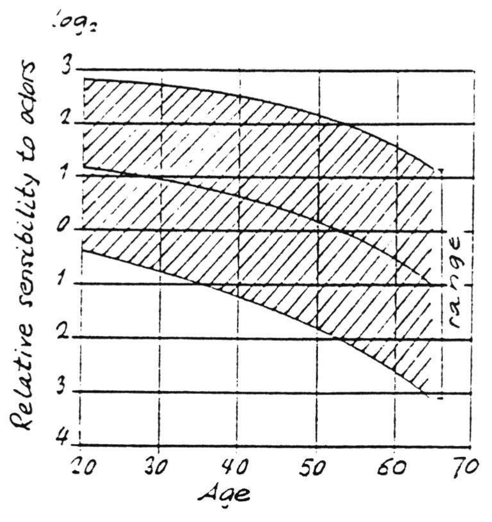

Figure 9: Average loss of sensibility to odours (adapted from Venstrom & Amoore, 1968)

Naturally, the picture of decreasing capacities that emerged until now, is far from complete. Some other aging phenomena, that were not mentioned yet, are decreased attention, slower decision making, poorer interaction with others, insufficient sleep, slower circadian adaptation in case of night work, and drowsiness. They all have their consequences for human performance.

Some observations

The foregoing leads us to the following conclusions:

- Aging phenomena do not call for attention at one specific age.
- Whether decreased capacities demand adaptation of tasks and work situations, depends on their nature.
- If decreased capacities ask for a change of the tasks and/or the work situation of a person, the solution take account of the present skills, knowledge and insight.
- When work-systems are developed or changed, the divergence of the capacities of the persons who are included should be taken into account.
- Compatibility of capabilities and job demands can be attained by:
  - 'personnel adaptation': by selection procedures, training, and sometimes aids, like spectacles;
  - adaptation of material system elements (including adaptation by means of adjustability and/or portability);
  - assignment of the jobs that have to be fulfilled (with a certain variety of those jobs regarding the required capacities), to the suitable persons;
  - adapting jobs to the capacities of available persons; such adaptations can concern system elements such as input, equipment, work method, pauses, etc.

In what now follows, some of these possibilities are closer considered.

Adjustability and portability of system elements
Examples of adjustability of system elements which may be useful in connection with interindividual disparities of properties, are:
- adjustable illumination and acoustic stimuli (with a view to declining vision and hearing);
- adjustable chairs, foot rests, tables, and visual displays, because of the interindividual, partly age-determined range of the body dimensions;
- keyboards are an example of system elements that usually should be portable.

Allocation of jobs in accordance with individual, possibly gradually declined capacities
Both in production and in provision of services a certain type of job may differ from workplace to workplace with regard to the required capacities and the resulting physical and/or mental workload. Then there may be sense in allocating the jobs in accordance with the different relative capacities of the present employees.
Bonjer (1962) has described interesting applications of this possibility. The physical working capacity of refuse collectors and milkmen was measured, and the required energy was determined. This factor depended on variables like customer density and number of floors. On the basis of these data, those concerned could be given work areas that were suited to their physical capacities.
In such cases, alternatives are as follows:
- area allocation according to age (for instance, criterion 50 years);
- area allocation according to individual physical capacities (this has clear advantages, because age is not the only factor determining physical capacities).

Nightshifts have specific drawbacks for elderly people, for instance, because of the often with work-at-night related lack of sleep. Therefore, nightshifts by elderly should be avoided as much as possible. Possible solutions are:
- companies have their early and night services carried out by younger employees;
- elderly shiftworkers are transferred to daywork (if possible without marked change of job). It is useful -and has been possible in several cases- to move their activities from the night to the daytime; certain investments in equipment may be necessary to that end (De Jong & Ruys, 1979).

Adaptation of jobs and work situations
If capacities of workers have decreased through the years, the following measures can be considered:
- lowering of physical load by mechanization (for instance of materials handling);
- improvement of information supply (possibly by better scales, more light, and written, instead of oral information);
- introduction of 'buffers' (in view of an increased spread of the times spent per unit of production);
- reduction in working hours,
- increase of time standards (to sanction longer time consumption per unit of production) and/or longer pauses.

If tasks are changed, training for the altered or new job may be important. There appears to be the inclination to devote insufficient time to the training of older employees - this is at least suggested in the Netherlands in 1988 (Rapportage Arbeidsmarkt, 1989).

Conclusion

In conclusion it should be pointed out, that if an elderly employee's function is to be altered, not merely his capacities, but his work goals should be taken into account too. One's work goals, together with one's experience are in constant development through the years. Factors that become increasingly important, are apparently fringe benefits, the physical condition, employment security, the boss, and cooperation (Hofstede, 1984).

Summary

Essentials of the foregoing are:

1. Most human capacities decrease after their maximum has been attained at an age of about 25. Some capacities decrease scarcely, others considerably.
2. Next to this age-related decrease, the interindividual spread of most capacities within an age class, is often an important factor.
3. If because of decreased capacities the job of an employee should be changed, his adapted or new job should be such that he can continue to make use of his earlier acquired capabilities. Moreover, changing work goals should be taken into account.
4. The compatibility of one's capacities and one's job may be furthered by 'personnel adaptation', adjustability and adaptation of material system elements, and such allocation of jobs that in all the optimum set of combinations of jobs and workers (both with their variety) is attained.

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Visual performance in night and dusk conditions

Results of questionnaires and laboratory tests on 517 drivers, from 16 to 84 years of age

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Summary
This study is aimed to provide data for road safety purposes on mesopic and dark vision in drivers. The population under study was a free sample of 266 professional drivers from 20 to 64 years of age and 251 ordinary drivers from 16 to 84 years of age. During a 45 minutes session, each driver had to fill a questionnaire and undergo 6 ergo-ophthalmological testing procedures. Spectacles and dioptric defects represented the primary factor of visual discomfort, when driving at night. It is the reason why, in our sample, ageing did not change the prevalence of visual discomfort, since the same proportion of people with spectacles were found before and after 40 years of age. The intensity of night driving was not depressed by age, feelings of discomfort or visual impairment in dark conditions. The visual output in conditions simulating night driving was much poorer in older subjects and people with glasses. Recommendations on an appropriate screening method for night driving and the improvement of road illumination were made.

Introduction
For road safety purposes, at dusk and night, illumination conditions should be adjusted to the visual capability of all drivers with a licence for night driving. This study is designed to provide data on mesopic and dark vision in young and older professional and non professional drivers, for road safety purposes (Bosquet et al, 1987; Meyer et al, 1988; Meyer, 1989). Conclusions are drawn from two sources: the results of questionnaires on feelings of visual discomfort; the results of laboratory tests, simulating the conditions of night and dusk which can be encountered on the road.

Method
Population under study
266 professional drivers and 251 non professional drivers were examined on a volontary basis. Professional drivers were bus drivers recruited in the T.P.G. transport company of Geneva. The non professional drivers were recruited with the help of the T.C.S drivers' association of Switzerland. Among these 251 drivers, a high proportion of females was found (43,8%), in opposition with the professional group. As expected, an uneven age distribution was observed, the professional group being limited to 64 years (figure 1). However, the mean age is about the same in both

groups, (41 +/– 9 years in professional drivers and 40 +/– 15 years in non professional drivers).
As far as eye correction is concerned (figure 2), about the same proportion of drivers wearing spectacles when driving at night was noticed in both the professional and the non professional population; corrected dioptric defects were a little bit less frequent in professional drivers.

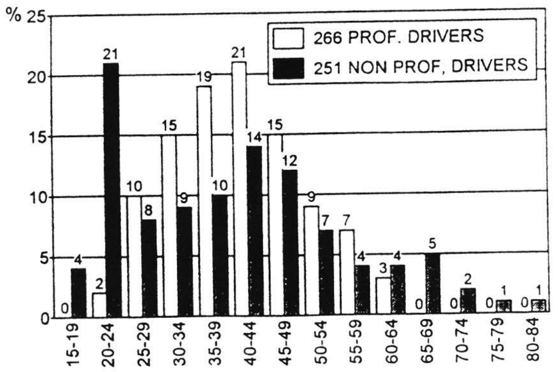

Figure 1

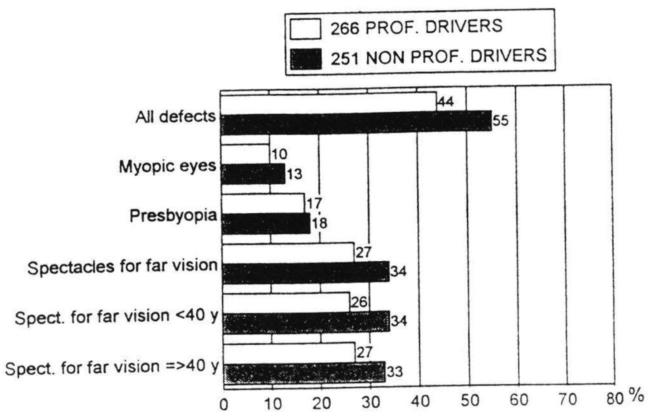

Figure 2

Visual testing
Besides the filling of a questionnaire, six visual tests were used, the aim of which was to place our subjects in conditions close to those of night driving :

- *Far and near visual acuity* were determined with a *Titmus-Vision-Tester* (Trotter, 1976; Corno et al, 1980). Let us stress, that with this device, bright targets are perceived on a dark background and that visual acuities are lower than with well illuminated Snellen charts).

- *Contrast sensitivity* was measured with a *Nyctometer Rodenstock* (first level, with or without glare source [Hartmann &Wehmeyer, 1980; 1981]).
- *Recovery time after glare* was measured with a *Mesoptometer Oculus* (corneal illuminance = 3.5 lux, acuity 0.16, contrast 8, [Aulhorn&Harms, 1970; Hartmann&Wehmeyer, 1981]).
- At last, our *acuity/luminance tests (C45 prototype, 2025 prototype and laboratory set up)* were also applied; subjects were requested to select the appropriate brightness necessary for them to detect the gap of Landolt rings, perceived against a dark surrounding, just at threshold, or for comfort or, at last, when hindered by glare (the procedure is described elsewhere [Meyer et al, 1988; Meyer, 1989]).

Questionnaires

Each driver had to fill a questionnaire. The first questions described the driver himself [age, sex, ocular status, number of years with a driving licence, frequency and intensity of vehicle usage (figure 3)]; with a series of 16 questions, the opportunity was given to the subjects to express their visual discomfort when driving at night (figure 4) and their appraisal of visibility condi-tions on the road (figure 5). We proceeded to establish several comparisons when they were made possible without methodological biais:

- younger drivers were compared to older drivers; we divided the population into two groups (≤ 40 and › 40);
- professional drivers were compared to non professional drivers;
- drivers with spectacles when driving at night were compared to drivers without spectacles when driving (the number of persons with contact lenses was too small to be taken into account);
- males were compared to females in the non professional group.

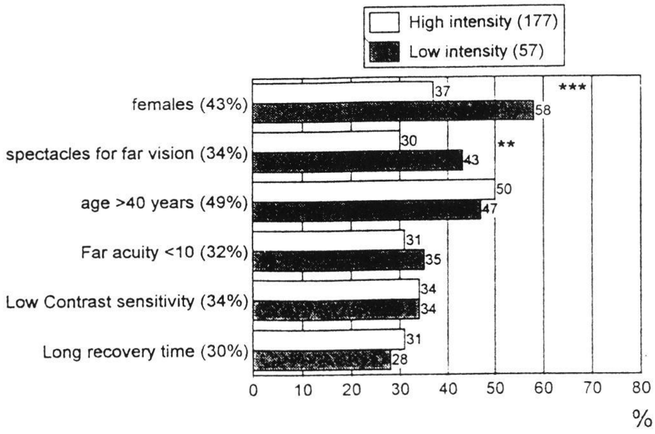

Figure 3

We also established an estimate of the "*intensity of driving*" at night, expressed by a combin-ation of number of days per week and the distance covered per day. It is interesting to point out here, that even in non professional drivers, night driving is needed to go to work and to come back from work (figure 3).

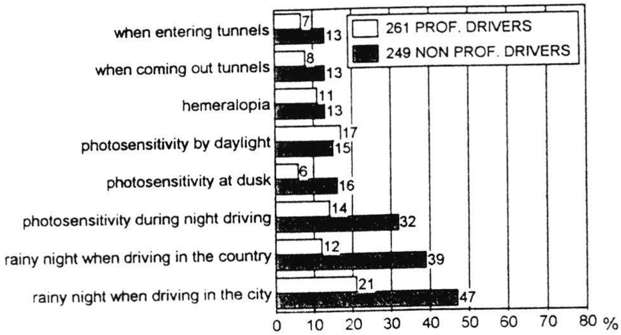

Figure 4

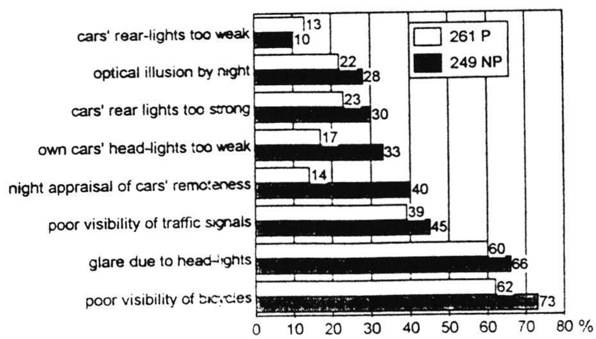

Figure 5

Results

Questionnaire

- According to figure 3, the proportion of females driving at night is lower than the proportion of males; moreover, people with spectacles avoid more night driving.
- Figure 4 shows that the proportion of perturbed drivers tends to be always higher in the non professional group. More important to notice is the fact that drivers are more handicapped when driving at night and particularly in rainy weather, with proportions reaching almost the half of the non professional population.
- It is obvious, *from figure 5*, that there is a great similarity between non professional and professional drivers in their appraisal of bad traffic conditions.

Very high proportions of them pointed out, as major deficiencies, the poor visibility at night of traffic signals and bicycles and complained of glare due to the head-lights of on-coming vehicles.

Other results, in short

- Female drivers report more eye discomfort by night driving [f = 45%, m = 25%] particularly when it rains [f = 48%, m = 33%]; the reasons for discomfort are related to on-coming cars (glare due to too bright head-lights) [f = 79%; m = 57%] or to front cars (reduced visibility of rear-lights which are considered as too weak) [f = 38%, m = 21%]; females report also more uneasiness in the appraisal of the speed of other cars [f = 49%, m = 28%].
- Drivers with spectacles report more discomfort when driving at night (non professional, with spectacles 45%, without 28%) particularly when it rains (professional, with spectacles 52%, without 21%).
- The intensity of night driving is not, for the active population, refrained whether by age or visual discomfort.

Visual screening

1) Drivers with poor visual output

Figure 6 summarizes our findings. Our visual tests did not show any difference between males and females; however, drivers with spectacles displayed a lower visual acuity in rather dark background and positive contrast, as well as more sensitivity towards glare; similarly, as expected, older subjects were less successful than younger subjects: differences were highly significant, outside recovery after glare.

Similar results were obtained in both non professional and professional drivers, provided that for the latter group, a more severe cut-off point was chosen (far acuity < 12, contrast without glare > 2/6, contrast with glare > 3/6, recovery time > 2.5 sec).

2) Effects of poor visual output on feelings of discomfort

Non professional drivers with lower visual acuity and longer recovery time after glare displayed higher prevalences of eye discomfort when driving at night. Similarly, in drivers with lower contrast sensitivity (figure 7), complaints on bad road conditions at night were significantly more frequent.

Mixing professional and non professional drivers, a *multiple factor analysis* with factors associated to tests produced the results appearing on figure 8. Due to our population under study, good results to our tests are associated with young subjects (to be found mostly in professional drivers), without dioptric defects detected by their eye doctor, without eye correction and who did not complain of discomfort when driving at night.

On the other hand, poor output with our tests are associated mostly with female and older drivers, wearing spectacles and complaining of visual discomfort when driving at night.

3) Individuals at risk : results obtained with our home test

Our *C45 acuity/luminance test* (Meyer et al, 1982; 1988) was very successful in detecting, by near vision, those operators which, one day or another, will suffer of poor adaptation to VDT work (also negative contrast and lower luminances). In far vision, results obtained with a laboratory set up are given in figures 9. In comparison with an emmetropic female of 20 years of age, myopic eyes (in a female of the same age) require an increase of luminance for the detection of Landolt rings and are responsible for a tremendous lowering of luminance levels which are necessary to produce glare. A similar but stronger effect is observed in an older male subject impaired by 3 dioptric defects: hyperopia, astigmatism and presbyopia; Like noticed in one presbyopic female subject of 62 year, aging induce, in these very hard test conditions (mesopic adaptation, negative contrast), a staggering drop of visual acuity.

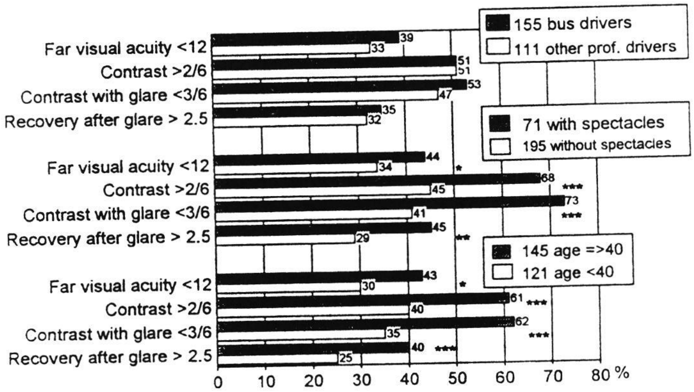

Figure 6

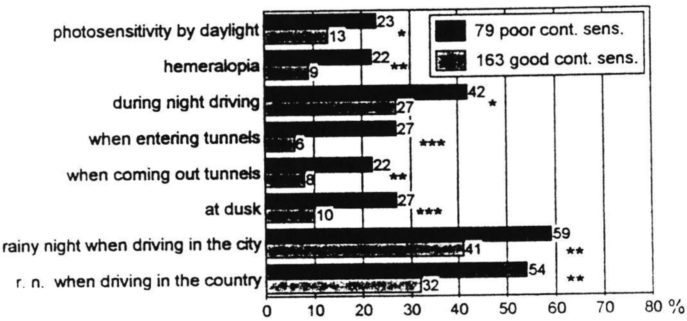

Figure 7

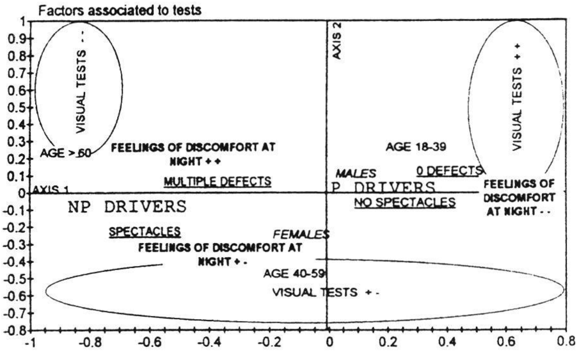

Figure 8

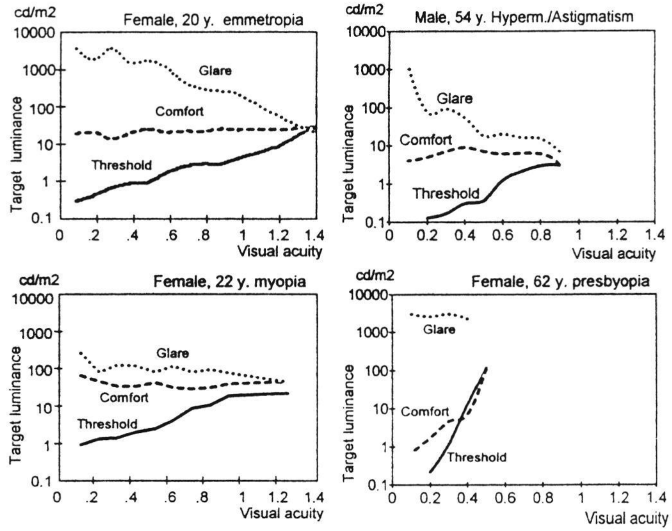

Figure 9

Practical conclusions for night driving

A) Strategy of visual screening

For a strategy of visual screening of night drivers (Rey&Bousquet, 1990), we suggest the following steps :

1. The most appropriate question : do you feel disturbed when driving at night ?
2. Screening according to the following risk factors :
   - age (up to 40 years of age versus more than 40);
   - spectacles when driving : yes or no;

- dioptric defects in younger applicants (myopia, astigmatism);

3. Recommended ocular tests for selected drivers :
   - far visual acuity, not in the way eye doctors measure it, but with devices favoring mesopic adaptation, negative contrast (clear targets on dark background), requiring the detection of figures and not letters, with inhibition by glare sources.

B) Recommended screening devices:

1. the Nyctometer of Rodenstock was powerful for the screening of drivers with difficulties when driving at night;
2. The predictive power of our home testing procedures (C45 test, 2025 test and laboratory set up) is rather fair, even at the individual level. Let us emphasize, however, that they are more prone to select negative than positive subjects, in other words, like many other visual tests, they display a stronger specificity (Rey&Bousquet, 1990).
   - Our home tests allow the detection of four groups of people: a first group with high output and no tendency to complain of those illumination conditions which are encountered on the road; a second group (with a high proportion of dioptric defects) which is easily impaired in those conditions, since they suffer of a too great sensitivity towards glare; a third group with a high proportion of people of middle age, with or without dioptric defects, which require more light to detect signals but who may withstand glare without problems, and, at last, a fourth group with a high proportion of older subjects with dioptric defects who, at the same time have lost their acuity in this particular luminous surrounding and are very sensitive to glare, even for rather low target luminances.
3. At last, ocular training with several ocular testing procedures, should help drivers in learning how to balance road difficulties with their own visual impairment.
   - It cannot be expected, from male non professional drivers, to decrease spontaneously their driving intensity because of their difficulties on the road at night. Are the females of our sample, who drive less, more conscious of their handicap when driving at night ?
   - Similarly, when driving at night is needed (or it just considered as more convenient or more fashionable) to go to work or to come back home, it cannot be expected of older drivers with poor visual output in dusk and night conditions, eventhough they are conscious of their handicap, to drive spontaneously less at night. Some kind of compulsory programme is thus requested for safety purposes.

C) Problems of glasses

- Ergonomic researches on glasses for night driving and for other activities should be welcomed. Once more, we like to stress that half of the population need spectacles to drive at night, for different eye deficiencies among which myopia in young people.

D) Ergonomics of cars and traffic lights

The following recommendations are valuable for all drivers, whether females or males, younger or older, with or without eye correction.

- In spite of international standards, the existing illumination conditions on the road at night were criticized by a high proportion of our sample of drivers. Further studies are required for a better adjustment of head-lights, rear-lights, traffic signals and bicycles' visibility to ocular sensitivity. Threshold values could be deduced from our work on hundreds of normal subjects (see our previous papers), taking into account those ocular deficiencies which are scattered among the common population of drivers and which are emphasized when using testing procedures which do not belong to the clinical tools of ophthalmologists.
- At last, the cockpit of modern cars is too dark; an equilibrium is to be found between a dark adaptation level to see cycles or pedestrians and a protection against glare due to head-lights and road signals. Perhaps a combination of appropriate spectacles and scattering of lights from car instruments inside the cockpit could be the cue.

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This study (No 54/88-JJM) was sponsored by the "Fonds für Verkehrssicherheit des Bundesamt für Polizeiwesen" of Switzerland. We thank very much the TCS drivers association of Geneva, as well as the TPG transportation company of Geneva.

The relevance of age for work in a warm humid climate

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Abstract
The relation between ageing and the reaction to heat stress has become an important issue in research in the last decades. Increasing life expectancy has resulted in an increase in the number of older people participating in the work force and in growing numbers of retirees. Epidemiologically, it has been shown that these older people are more susceptible to heat stress than their younger fellow citizens, resulting in a larger mortality and morbidity rate in the older groups. Recent research has questioned the causal relation between age and heat tolerance in the light of changes in physical fitness and anthropometry with age. the present study was designed to single out the effects of age, build and fitness on heat tolerance. For this purpose, 60 healthy subjects in the age range of 18 to 73 years old (+ 10 per decade) of various fitness levels (VO2max) worked at a fixed load in a warm, humid (35°C, 80% rh) environment. Multiple regression analysis of the heat strain parameters body core temperature and heart rate showed that the effect of age was not significant, and that commonly observed "age" effects will actually be caused by differences in physical fitness and anthropometric measures in the tested population.

Introduction
The relation between ageing and the reaction to heat stress has become an important issue in research in the last decades. Increasing life expectancy has resulted in an increase in the number of older people participating in the work force and in growing numbers of retirees. Epidemiologically, it has been shown that these older people are more susceptible to heat stress than their younger fellow citizens, resulting in a larger mortality and morbidity rate in the older groups. Research has attempted to investigate the causes for this deterioration in heat tolerance. Early studies showed increased strain in response to heat in older people, but later these results were questioned because the studied groups differed in physical fitness. Other researchers tried to compensate for the confounding fitness factor by matching young and older subjects for their fitness level. This approach has resulted in sometimes equal responsiveness to heat stress (Kenney, 1990), sometimes higher strain (Kenney, 1988) and sometimes even a lower strain in response to heat stress (Pandolf, 1988) in older

subjects. Matching older and younger groups exactly for all their characteristics except age was never completely achieved in the mentioned studies though. Also the relevance of observed age related differences in heat stress response in matched groups received little attention. Therefore, the present study was designed to study the relevance (if present) of age related differences in heat stress response in relation to physical fitness related differences. For this purpose, a test group was selected in which no correlation was present between the subjects fitness level and their age, but in which large variations of both parameters within groups were present.

Methods

A group of 73 subjects with a wide range of activity patterns and age were asked to participate in the experiment. All subjects were medically screened and gave their informed consent. Physical fitness was determined by measuring maximal oxygen uptake on a treadmill, using a modified Balke protocol. Body composition was measured by skinfold measurement and under water weighing. After the subjects characteristics were defined, they performed a heat stress test. The heat stress test consisted of a 90 minute exposure to a warm humid climate (35°C, 80% rh), in which they first rested for 30 minutes and subsequently cycled on a reclining bicycle ergometer at an external work load of 60 Watts for the remaining 60 minutes. Data on heart rate, rectal temperature, average skin temperature, weight loss, blood pressure and forearm blood flow were collected throughout the experiment. The exposure was terminated when subjects reached a heart rate above 90% of their personal maximum, or when rectal temperature increased above 39°C.

Final rectal temperature, heat storage and heart rate data were analyzed for their dependence on individual characteristics by multiple regression analyses, using the statistical package SYSTAT (Wilkinson, 1990).

Results and discussion

The physical characteristics of the subject groups are presented in Table I. All but three subjects were able to finish the ninety minutes heat exposure. Fourteen subjects were excluded from the data set as their data would cause the correlation between O_{2max} and age to become significant.

Table I: Physical characteristics of the subjects (n=56).

	mean	sd	minimum	maximum
age (years)	44.4	14.8	20	73
Vo_{2max} ($l \cdot min^{-1}$)	3.03	0.65	1.86	4.44
fat (%)	21.9	6.3	9.9	40.4
weight (kg)	72.5	12.1	49.8	104.6
height (cm)	173.9	7.5	157.1	192.0
bsa (m^2)	1.87	0.17	1.52	2.26
surf/mass ($m^2 \cdot kg^{-1}$)	0.26	0.002	0.021	0.031

In the final data set, no correlation between fitness (O_{2max}), age and body fat content was present. Thus the requirement for the use of regression analysis of independence of the individual parameters was met. This is illustrated in Figure 1.

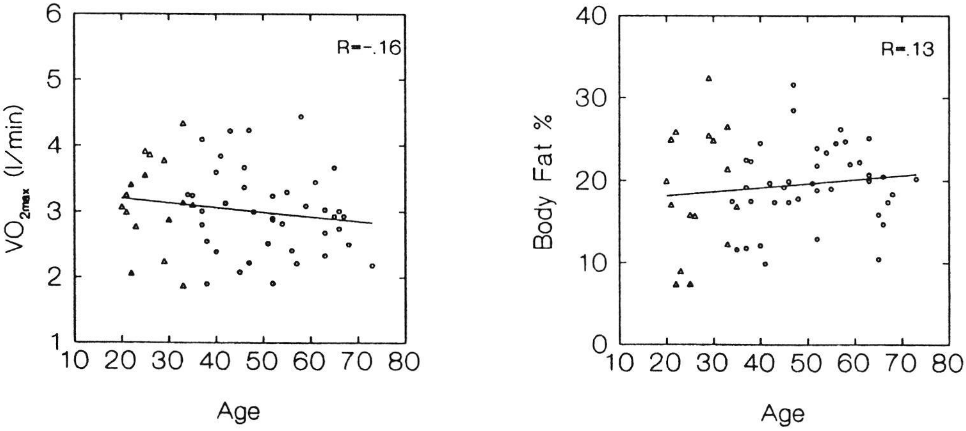

Figure 1, the relation between fitness and body fat content and age. Each data point represents one subject.

Final rectal temperature and body heat storage at the end of the heat exposure correlated significantly ($P<.01$) with the subjects' physical fitness level expressed as absolute O_{2max} ($L \times min^{-1}$), as O_{2max} per kg body weight, or with work load expressed as percentage of maximal oxygen uptake. No significant effect of age on heat storage and rectal temperature was observed, as illustrated in Figure 2. After correction of rectal temperature and body heat storage data for the physical fitness effect, neither age nor body composition appeared to have a significant influence.

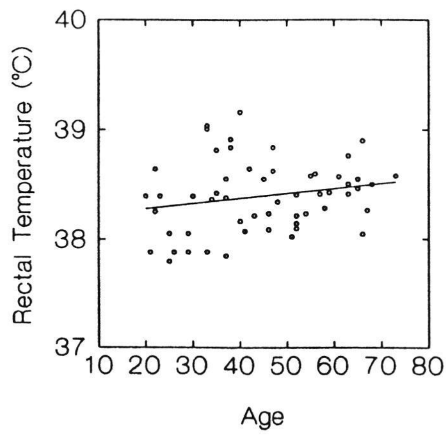

Figure 2, the relation between rectal temperature at the end of the heat exposure and the age of the subjects

The question whether the effect of age, observed in other studies is relevant compared to the effect of physical fitness is thereby answered in a negative sense. Though a small age effect may exist, as observed in literature (Pandolf, 1988, Kenney, 1988), this is only measurable when groups are matched precisely with respect to their physical characteristics. Once natural variation in physical fitness is introduced in the test population, the age effect appears to be negligible, compared to the fitness effect.

Heart Rate

Similar reasoning can be applied to the results for heart rate. No direct relation between heart rate and age was observed (Fig. 3). For absolute heart rate, an age effect was observed once the data were corrected for the physical fitness effect, however. This effect is caused by the age-related decrease in maximal heart rate. In the test population, maximal heart rate was shown to relate to age as: HR_{max}=218-.72*age, which is similar to the relation described in the literature for large populations. This age effect on heart rate means that when a young and an old subject have an equal O_{2max}, the young one will have a higher heart rate for the same workload. When heart rate is expressed as percentage of maximal heart rate, no age effect is present however. Thus, though the older has a lower absolute heart rate compared to his younger, equally fit colleague, the physical strain is equivalent.

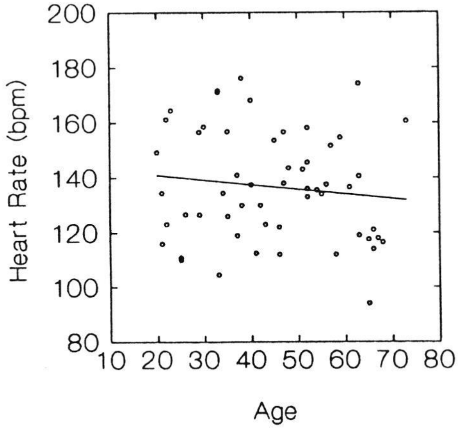

Figure 3, the relation between heart rate at the end of the heat exposure and the subjects age

Conclusion

No relevant age effect on heat stress response in body core temperature and heart rate (expressed as percentage of maximal heart rate) is present when comparing age groups with equal average O_{2max}. The reduction in individual absolute maximal heart rate with age results in lower heart rates for equal work loads in older subjects.

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Older drivers and attentional demands: consequences for human factors research

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Abstract
On the basis of accident data and questionnaire results it was argued that situations with time-pressure and requirements for simultaneous activities are important problem areas for older drivers. Many different elementary impairments may contribute to these global age-related problems. These may lie both on the level of receptor- and effector organs and on the level of cognitive functioning, particularly attention. Such elementary impairments are discussed, giving most emphasis to the cognitive ones because correlations between accident involvement and test performance suggest that their effect is more detrimental than that produced by impaired eye and effector functions. Both the effects of normal ageing and ageing-related diseases (eye diseases and dementing diseases) are discussed. Technological and educational innovations have a potential for making the traffic system more user-friendly for older drivers with perceptual and cognitive impairments. As the car is very important for the independent living of older persons, there is an urgent need for ergonomic research on older drivers utilizing new technology and compensatory cognitive strategies which reduce the requirement for simultaneous activities and which reduce time-pressure. Some possible directions this research might take are discussed.

Introduction

When accident statistics of middle-aged and older drivers are compared, it appears that older drivers and particularly those above 75 years of age run significantly higher fatality- and injury risks (Traffic Safety of Elderly Road Users, 1985; Transportation in an Aging Society, 1988). This high involvement of older car drivers in the more serious accident consequences, is thought to be the result of two factors, viz. the increased physical vulnerability with increasing age (Evans, 1988) and the overinvolvement in certain types of accident which tend to have severe consequences, particularly multi-vehicle accidents on intersections.

Older drivers have consistently been found to be overrepresented in such accidents and this increases further in very old drivers, above 75 or 80. Particularly the problem arises when the older driver has to turn left across a lane of traffic (turn right in left driving countries). Not only are older adults overinvolved in such crashes, also they are significantly more frequently at fault, often failing to yield the right-of-way and/or overlooking traffic signals or stop signs (Traffic Safety of Elderly Road Users, 1985; Garber and Srinivasan, 1991). The consequences of such accidents in which the older driver's car is typically hit with high speed by a vehicle coming from the driver's side (Viano et al., 1990; Hakamiis-Blomqvist, 1993) are often serious, particularly for the older driver him/herself.

In ''Traffic Safety of Elderly Road Users" (1985), the situation eliciting these problems is described as requiring "information treatment and decision making under a severe time constraint". This time-constraint is particularly problematic for older drivers because their speed of information processing and movement is slower on average than in younger adults and because they less easily utilize opportunities for parallel information processing.

That divided attention and time-pressure are problematic aspects is not only evident in the accident circumstances. Also when older drivers are questioned about problematic situations and actual driving performance, their answers indicate these problem areas. This is illustrated by a study we performed in the framework of an EEC project on Road-Traffic-Informatics for older drivers (Van Wolffelaar, Brouwer and Rothengatter, 1990; Brouwer, Rothengatter and Van Wolffelaar, 1992; Brouwer, 1994).

Many different elementary impairments and diseases may contribute to these global age-related characteristics and of course there is great individual variability in their nature and severity. Elementary impairments may lie both on the level of receptor- and effector organs and on the level of cognitive functioning, particularly attention. These elementary impairments will be discussed below. Most emphasis will be given to the cognitive factors because correlations between accident involvement and test performance suggest that their effect is more important than that produced by impaired eye and effector functions (Shinar and Schieber, 1991; Johansson et al., 1993).

Ageing-related limitations of information processing

Elementary visual impairments

In general the quality of all visual functions decreases with increasing age. The degree and rate of these decreases vary considerably between functions and individuals (e.g. Transportation In An Aging Society, 1988; Shinar and Schieber, 1991). The traditional test of static visual acuity in a well lighted environment belongs to a category of function tests which is only mildly sensitive to the effects of ageing. Static visual acuity is not thought to be a particularly relevant function for driving. Function tests which have more important consequences for vision in driving are contrast sensitivity (Hyvarinen, 1993), glare sensitivity and detection of motion (lateral and in depth). Age effects on these functions are generally larger than those on visual acuity.

Ageing-related eye-diseases

Four age-related ocular conditions, cataract, macular degeneration, open angle glaucoma and diabetic retinopathy are held to contribute considerably to the decline of visual function described above (Klein, 1991). With cataracts, the eye lenses become unclear. In early cases, acuity is not much influenced but glare sensitivity, colour perception and night vision already significantly suffer. Fortunately cataract extraction, a common operative procedure, can often successfully restore vision. Age-related macular degeneration is a condition which selectively damages the macula, the central area of the retina required for detailed vision as in reading traffic signs. Only a small percentage of eyes with macular degeneration can be treated successfully by operative procedures. Macular degeneration by definition leaves peripheral vision intact. This is not the case with open-angle glaucoma which is often characterized by high intraocular pressure associated with damage to the optic nerve. There is often a gradual constriction in the peripheral visual field of which patients are not aware and this may interfere with seeing cars or pedestrians coming from the side. Persons with diabetes, a relatively frequent condition in older adults, are at higher risk for developing cataracts and retinopathy.

In which stage of disease and to which extent these visual diseases and their treatments precisely influence visual functions like visual acuity, motion perception and contrast sensitivity is not known. It is quite likely, however, that further investigations into potentially preventable risk factors for these conditions would have a positive effect on older driver safety and mobility.

Troublesome as functional losses in these areas may be, their existence does not necessary imply increased accident risks because it is largely under the control of the driver whether he gets himself into a situation where such impairments become a limiting factor. A classical example is night driving. This is particularly problematic for many elderly drivers, but so many elderly drivers refrain from night driving that they are actually underrepresented in night-time accidents. Of course one may wonder in how far this is a compensation and in how far it is simply produced by a difference of life style between older and younger adults (Joly and Brouwer, 1995). Whatever the precise background may be, however, the correlations between lower lèvel impairments of visual function and accident involvement are generally low. Also, there are a number of publications with descriptions of individual cases and small groups of patients with rather extreme functional visual impairment with very good driving safety records (Warmink et al., 1992; Hyvarinen, 1993).

Stronger relations have been reported for higher level perceptual, attentional and cognitive impairment, certainly when impairment is considerable as in beginning dementia. In this case, the compensation does not appear to work as smoothly. For example, recent studies reviewed by Johansson et al (1993) indicate a 4 to 18 times higher risk of traffic accidents for drivers with dementia compared with elderly controls. Also, Ball and Owsley (1991) report a significant correlation between performance on a mental status test (a screening test for dementia) and involvement in intersection accidents. As in the general literature on older drivers, the problems most sharply emerge at intersections and when changing lanes. Relatively speaking these situations are characterized by time pressure and/or the requirement to do several subtasks simultaneously. I will now discuss normal and abnormal age changes on a number of higher order visual and cognitive functions.

Higher order visual and cognitive impairments

Focused attention

Based on research with card sorting tasks, Rabbitt (1965) suggested that the sensitivity to distraction by irrelevant visual stimulation increases with age. Later research with many psychological tasks has generally supported this claim but recently it is doubted whether this is a specific effect or just another manifestation of the "general law" that any cognitive task that is difficult for young adults, is more difficult for older adults, independent of the specific characteristics of the task (for a review see McDowd and Birren, 1990). Focused attention tasks which require an active attentional control process (localization of stimuli and feature integration) to discriminate relevant and irrelevant stimuli are particularly difficult. Irrelevant background stimuli do not appear to be more distracting for old than for younger subjects.

Visual search and analysis

As people age, a number of higher order abilities related to visual analysis and visual search decline (e.g. Salthouse, 1982). Clinically, this is clearly manifested in the performance on paper-and-pencil tests like the Embedded Figures Test (visual analysis) and the Trailmaking-A test (visual search). In more experimental tasks of visual analysis and visual search, making use of reaction time paradigms, the difference between young and old subjects is again roughly proportional to the difficulty of a task. Difficulty is estimated on the basis from the average reaction time of young adults on the task. At this, it does not seem to matter what specific task variation caused the degree of difficulty. The main theoretical explanation for this state of affairs is a cumulative random loss of links in neural networks with ageing (Cerella, 1990).

Brouwer, Rothengatter and van Wolffelaar (1988) demonstrated that in a sample of older drivers (60 - 87 years) very low performance on speeded tests of visual search and analysis (e.g. the Trailmaking-A test) went together with insufficient grades in the test for advanced drivers. This is a test-ride in the subjects' own cars in representative driving situations which is judged by an independent driving expert. From the general literature on driving and visual search it is known that performance on visual analysis and search tests and driving performance are moderately correlated (e.g. Mihal and Barrett, 1976). For visual search (Embedded Figures Test) this includes accident involvement.

Divided attention

Above mentioned problems of older drivers are observed in a situation when one task must be performed alone. In real driving often several tasks must be performed simultaneously. Besides keeping the car on course, also peripheral traffic signs must be detected and it must continuously be assessed whether approaching traffic is on collision course. On top of that, one may have to find one's route, when in an unfamiliar environment.

The gerontological literature on performance in divided attention tasks reveals that ageing-related impairment often increases, even when performance differences in single-task baseline performance are controlled (Ponds, Brouwer and van Wolffelaar, 1988; McDowd and Birren, 1990). The magnitude of this effect is dependent on the nature of the tasks to be combined. We have also demonstrated this for a combination of tasks in a dynamic driving simulator (Brouwer et al., 1990, 1991, 1992) performed by younger (25-40 years) and older (above 60 years) healthy experienced drivers. In the first two studies a dynamic lane tracking task had to be combined with a discrete visual analysis task (figure 1).

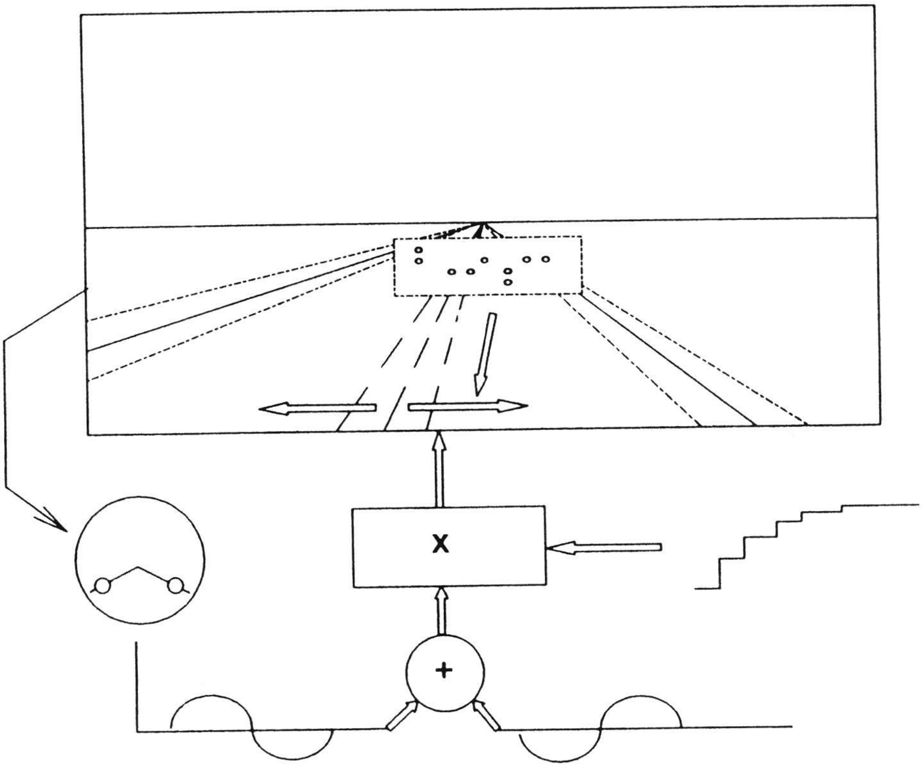

Figure 1. Schematic view of the display during lane-tracking with secondary visual analysis task. Road boundaries move laterally to left and right according to an unpredictable low-frequency "side wind" signal. This can be compensated for by steering. The steering wheel also contains the push-buttons for the dot-counting task. X = the individually adapted average amplitude of the side-wind signal (Adapted from Brouwer, Waterink, Van Wolffelaar and Rothengatter, 1991)

Both tasks required the same point of fixation (the visual dot-patterns were presented in the middle of the road display, just below the horizon). The response required in the steering task was always manual while in the visual analysis task, it was either manual (pushing horn-buttons on the steering wheel) or vocal (saying yes or no).

Before combining the tasks, each was practiced separately and the task difficulty of each task was individually adapted on the basis of single-task performance. In both studies it was found that older drivers have greater performance losses relative to the single-task conditions than young adult drivers, but that this effect was much stronger in the manual-manual condition than in the manual-vocal condition. On a perceptual and cognitive level, these conditions are completely similar, so in these tasks the locus of the problem was sought on the motor programming level, specifically in the integration of two simple manual skills. The ageing-related divided attention effect was much stronger on the lane-tracking task than on the visual analysis task. In the most recent study, a third task was added, viz. a peripheral detection task.

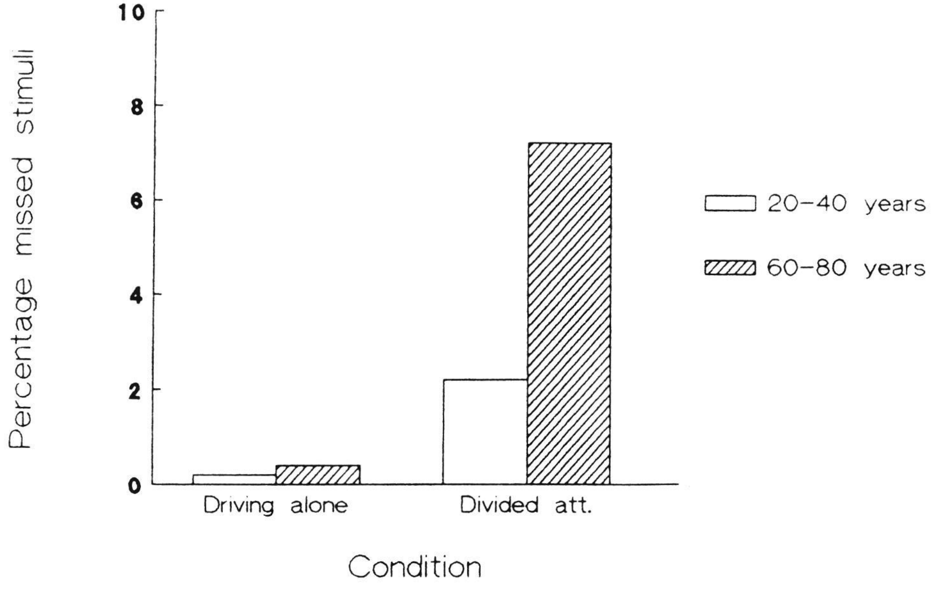

Figure 2. Percentage missed peripheral stimuli in driving alone and in divided attention conditions separately for young and older drivers (data from Brouwer, rothengatter and Van Wolffelaar, 1992)

Besides the effects already described, it was now further shown that the older drivers missed significantly more peripheral stimuli than younger adult drivers in the multi-task conditions (figure 2). Again this effect was more outspoken in manual-manual conditions than in manual-vocal conditions.

Ball and Owsley (1991) also looked at peripheral detection in a divided attention situation, in their case in purely perceptual tasks with very short duration of presentation of the peripheral stimuli. In a sample of older drivers they found a strong correlation between a measure of peripheral detection (the so-called Useful Field of View: UFOV) and involvement in intersection accidents (but see Brown et al., 1993). The score with regard to UFOV was based on performance both in single-and dual-task situations, so the attentional and sensory/perceptual contributors to the effect cannot be disentangled. Because they measured various aspects of eye-health and elementary visual function (e.g. visual acuity and contrast sensitivity) alongside with the UFOV measurements, they were able to show, however that poor UFOV could occur both in persons with and without significant elementary visual dysfunction.

Thus, it appears that there is relevant gerontological information in dual-task performance scores which is not already contained in the single-task scores. A theoretical explanation forwarded by Brouwer et al. (1990) is that in older persons, task performance puts a greater claim on general cognitive resources, i.e. on multi-purpose information processing channels which can be allocated to one or another task. By that cause, they have less spare capacity left when performing in a single task at maximal capacity (limited to this maximum by some other factor), but this will not be noticeable in behaviour. Cognitive resources may become a limiting factor when two tasks have to be performed simultaneously. It appears to be the case that even well-practiced driving skills like lateral position control require more processing resources in older drivers. Contrary to expectation, lateral position control was found to be more sensitive to divided attention conditions than a relatively unpractised task to be combined with in two separate studies (Brouwer et al., 1991; Korteling, 1994).

Flexibility of Attention

According to Parasuraman and Nestor (1991) the component of attention which has been implicated most as a determinant of accident involvement in professional drivers is attention-switching. In a number of studies that they reviewed, moderate correlations were found, particularly in auditory tasks involving dichotic listening. Also the correlations reported were higher for samples including older professional drivers than in those only involving younger subjects.

Already in the older psychological literature on ageing, it was observed that with increasing age it becomes more difficult to spontaneously switch from one method of problem solving to another one when the type of problem changes. This was described as cognitive rigidity (see McDowd and Birren, 1990), the opposite of cognitive flexibility. In attention research, flexibility refers to the process of alternately monitoring two or more sources of input. If attention is flexible, task performance will deteriorate less, relative to performance in a single source monitoring task, than if it is not. Clinically, the Trailmaking-B test may be viewed as a test of attentional flexibility (and visual search). The increase of solution time relative to the single-source A-version gives an indication of flexibility.

The effects of impaired flexibility and divided attention on the safety of driving may be limited as long as the driver can limit exposure to complex and rapidly changing situations by decisions on the strategic level, e.g. only using the car in a well known environment and when visual conditions are good. Strategic level decisions can normally be made in a situation without any time-pressure and not requiring flexibility and divided attention. Once a driver with poor flexibility is on the road, however, on the tactical level of the driving task, one would expect such a person to adapt much less selectively to changing situations, e.g. driving at a constant (probably low) speed in a variety of situations, where some would allow higher speed and others might even require a lower speed than the one chosen, given the abilities and skills of the driver. This prediction can only be investigated when test performance is related to driving behaviour in actual driving situation requiring adaptions to changing task demands and to own abilities and skill. It is expected that a new generation of dynamic driving simulators featuring complex virtual driving environments will play an important role in this investigation (e.g. Van Winsum and Van Wolffelaar, 1993; De Waard et al., 1994; Van der Hulst, 1994). They involve driving in a realistic virtual environment in which other (artificially) intelligent traffic participants interact with the human driver in the test car. Also the manual and pedal controls and the dashboard in the test car are part of the virtual environment, e.g. realistically changing their characteristics with its (virtual) speed and position. The spatial characteristics of this virtual world (e.g. the types of intersections) and the type of information given to and required from the driver, can be varied at will, according to the experimental questions asked.

Dementia: ageing-related cognitive and perceptual disability

Dementia, mainly attributed to Alzheimer's Disease (AD) is a relatively frequent condition in old age. According to recent American estimates reported by Evans et al. (1989), 3 % of those between 65 and 74, 18.7 % of those between 75 and 84 and 47.2 % of those above 84 probably have AD. Together this makes for a total of 10.3 % of the 65+ population; if dementias from other aetiologies are included, the total percentage may be as high as 15 % . In these estimates, mild cases who can still live independently are included. About 4 to 5 % of individuals over 65 have dementia severe enough to prevent them from living independently (Transportation in an Aging Society, 1988). So approx. 10 % of the population above 65 will be (mildly) demented and living independently. As in many countries driving a car is very important for independent living, driving by mildly demented persons is quite a frequent phenomenon (Kaszniak, Keyl and Albert, 1991).

Almost by definition, patients with dementia are severely impaired on tests of higher cognitive abilities. In all of the functional categories distinguished above, strong effects of (mild) dementia, usually dementia of the Alzheimer type, have been documented (Parasuraman and Nestor, 1991; Nebes and Brady, 1992; Parasuraman and Haxby, 1993). In comparison with these effects, the effects of normal ageing seem modest as is illustrated in figure 3.

In this figure, peripheral detection in the driving only and multi-task conditions of the driving simulator experiment described above is presented separately for healthy older drivers (n=24, 6080 years) and three consecutively referred patients with probable AD from a recently started research project. The difficulty of both the driving task and the additional task in the multi-task condition had been adapted to individual ability in an earlier stage of the experiment.

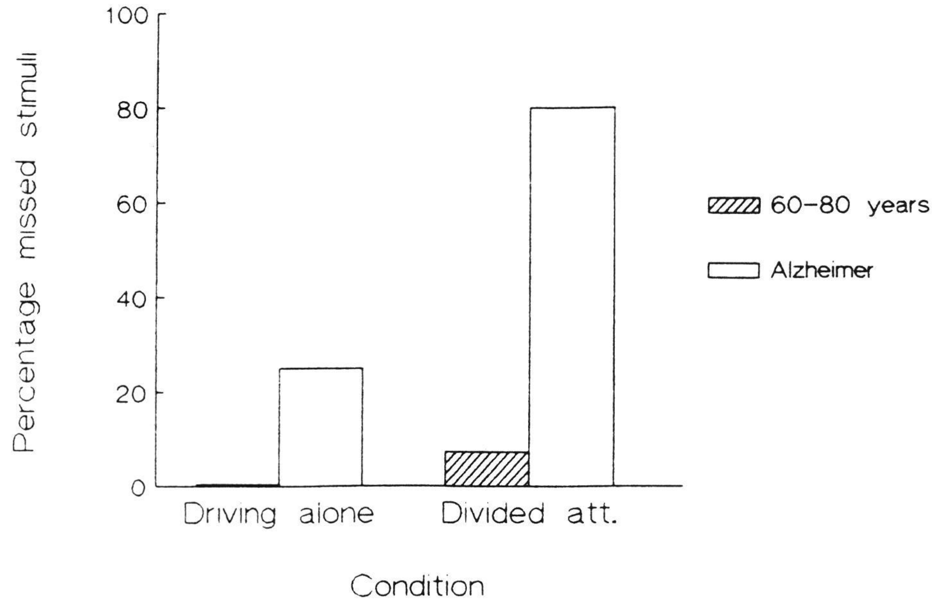

Figure 3. Percentage missed peripheral stimuli in driving alone and in divided attention conditions separately for older drivers (data from Brouwer, Rothengatter and Van Wolffelaar, 1992) and three consecutively referred patients with probable Alzheimer's disease

In the light of this evidence it does not seem surprising at all that patients with beginning dementia appear to be overrepresented in traffic accidents. Kaszniak, Keyl and Albert (1991) conclude from their review of the literature on driving habits and accident involvement of (mildly) demented patients:

"Thus, overall, the available empirical data appear to support the conclusion that dementia and particularly AD- is accompanied by increased crash risk. This heightened risk may obtain even though patients with dementia are limiting their driving"

According to Kaszniak and co-workers the most appropriate driving question for persons with progressive dementia is when they should stop driving. It is doubtful whether the patients or their family can judge on this issue themselves. In a number of studies, it has been demonstrated that there is not much relation between judgements of own disabilities and objective assessment thereof in demented patients (in Kaszniak et al., 1991). Also existing (re)licencing methods are not very helpful because of their emphasis on elementary visual function and general health. So there appears to be a need for standardized and validated testing methods for screening and, once a person has been screened as a risk, in depth assessment of fitness to drive in patients with mild dementia.

Although the screening instruments will have to be (neuro)psychological tests of some kind, the in depth procedure should preferably include a standardized driving test in actual traffic. We sometimes observe a strong discrepancy between the very poor performance on clinical tests of all of the items mentioned above and the good performance on certain parts of the actual driving skill, particularly in demented patients with much driving experience and well preserved visual and motor functions. This discrepancy may be understood in the framework of the cognitive schema theory presented by Shallice (1982). Overlearned traffic skills are correctly elicited automatically by environmental cues through the mechanism of "contention scheduling" and do not require the involvement of "supervisory attentional control". In such cases it may be observed that handling of the operational and tactical aspects of the driving task are managed still, but that strategic aspects (route planning, spatial orientation, route-finding and remembering where to go) fail. Often, the tasks of route planning, route finding and route-guidance are taken over by the not demented spouse (in the Netherlands often the wives, as in most cases older women do not have driving licences).

Reducing time pressure and parallel processing requirements

In the analysis of driving competence of older persons, time-pressure and requirements for simultaneous activities were singled out as task features which are particularly problematic. Time-pressure and simultaneous activities may be difficult for any age group, but the effects are relatively more pronounced in older drivers. Paraphrasing an ergonomic slogan, these problems may be solved by bending the tool (modifying the infrastructure and the car) and by bending the person (driver education and selection). Because of the increasingly important role of the private car in the mobility and independence of older persons (Transportation in an Aging society, 1988), the emphasis should be on making the infrastructure and the car more user-friendly. Also older drivers should have the opportunity for compensatory driver training and driver education. In my opinion there is an urgent need for applied research in which different methods which reduce the requirement for simultaneous activities and which reduce time-pressure are investigated in specific situations. This concerns both educational and technological solutions.

Measures aimed at the drivers

Measures aimed at older drivers could include training, information, counselling, and selection. A general framework for understanding compensatory driver behaviour is provided by Michon (1979). It describes traffic behaviour as a hierarchy of subtasks on the strategic, tactical and operational level. Analysis in terms of this hierarchical framework shows that time pressure and parallel processing requirements exist in particular on the operational level. However, decisions on higher levels can strongly influence the probability of running into time pressure on lower levels (e.g. when driving slower near a school, there will be less time pressure if a child crosses unexpectedly). In this framework, intervention could take two directions, either bringing "at risk" drivers to the use of strategies on higher levels which decrease the probability of time-pressure on lower levels. Alternatively, intervention could be aimed at improving skill on the operational and tactical level. However, this would be feasible only in those subjects with a relatively low level of skill in combination with relatively well preserved general abilities. Because of large individual differences between older drivers, both in terms of skill and in terms of impairments, interventions should ideally be addressed at individual persons or small groups of person with comparable characteristics.

Measures aimed at the infrastructure
In general, infrastructural modifications which appear to be beneficial to older drivers in particular, are those which reduce the speed of cross traffic at intersections. An example are the small roundabouts widely used in Australia and the UK and increasingly being used in the Netherlands too. Another suggestion is that traffic situations should be as predictable as possible because in that case the older driver will be maximally able to profit from the opportunities for anticipation (particularly important in the case of demented drivers). Examples are a consistent system of road signs which are timely and well placed and a standardization of the lay-out of roundabouts and intersections. A third general suggestion would be that intersections should be designed such that decisions are required sequentially (e.g., providing traffic islands) instead of simultaneously.

Measures aimed at the car
An issue raised by the accident literature is the necessity of giving special attention to passive safety measures which are optimally suited to protection of frail elderly. An example is side protection. According to Viano and co-workers (1990), 64 per cent of the front-seat occupants fatally injured by side impact crashes in the U.S.A. are over 50 years old and 36 per cent are over 70 years old. Also potentially important for many older drivers, particularly in Europe, is the older technology of power steering and automatic transmission. An important argument for this is the notion that in many older persons the execution of motor skills, even when well learned, appears to become less automatic than before (see above).

An approach which may hold promise for the future is the prevention of intersection accidents through the use of electronic driver support technology. E.g., one could think of a system which gives a clear visual warning in the useful field whenever a stop sign is encountered. Because of its potential as a rehabilitation tool for older and impaired drivers, new technologies on the road and in the car are important areas of research and development. In order to arrive at technology which is useful for older drivers, it will be necessary to evaluate all equipment that requires some form of interaction during the execution of the driving task, preferably with drivers of different age groups, but if this is too costly, certainly with older drivers. Operating auxiliary equipment which is easy and uninterfering for young drivers is not necessarily so for older drivers. Also the acceptance of the new technology may be quite different in older and younger drivers. For these reasons the effects of (different user interfaces for) systems giving feedback with regard to traffic violations on behaviour and subjective evaluation (in the framework of the DETER project of the DRIVE-2 program) are currently investigated with older and younger drivers at the Traffic Research Centre (De Waard, 1994; Van der Hulst, 1994).

Another DRIVE program, the development of intelligent co-driver systems according to the GIDS or ARIADNE concept, is also potentially important for older drivers (Michon, 1993). Basically the aim of the co-driver is to only present information when the driver needs it and can handle it. Such systems can take the basic abilities and skills of the driver as well as the current environmental demands into account. For example, the visual warning for a stop sign in the useful field of view might only come into action, when driver behaviour -as assessed from sensors in the car and compared with a model for that particular driver- indicates that the sign has not been noticed. With regard to strategic aspects of the driving task in a previous section, I gave the example of the wife of a demented driver acting as an intelligent co-driver with regard to route guidance. Presumably, also in this area, intelligent new technology could help, for example in the case when the spouse is not such a good route-finder either or when there is no spouse. For the present, however, the human co-pilot still appears to have a major lead in terms of friendliness of the user-interface.

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Pilot workload evaluated with subjective and physiological measures

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Abstract
The aim of the present study is to validate different measures for mental workload. Ten aspirant fighter jet pilots flew several scenarios in a flight simulator. The scenarios were divided into segments with different levels of task load. During the flight, heart rate, respiration and blood pressure were recorded. After the tasks, subjects rated the workload for segments of the scenario with the NASA-TLX and the BSMI (a Dutch effort scale). Furthermore, cortisol was measured on the training and experimental day (before and after each scenario).

Heart rate, heart rate variability and several respiratory parameters reflected the changes in task load. Blood pressure was not systematically affected by task load. The BSMI was more sensitive than the TLX; the task load effect was stronger and the correlations with the physiological parameters were higher. Cortisol levels were slightly increased on the experimental day but the post task levels did not differ from the pre-task levels. There was a correlation between mean cortisol levels and performance: subjects with high cortisol levels performed poorly.

Introduction
Mental workload of pilots is often high due to the complexity of the flying task. Besides flying an airplane, the pilot has to navigate, communicate and monitor the system. In battle situations, some other tasks like finding targets and avoiding enemy attacks also have to be performed. To get more insight in the mental load of a pilot it is important to develop measures of mental workload. In this paper the results of a laboratory experiment are discussed in which several physiological and subjective measurement techniques were evaluated.

Mental workload is an elusive concept that cannot be tackled by only one measure. Therefore, an integral approach was chosen in which mental workload was evaluated with several measurement techniques: subjective ratings, performance and physiological reactivity.

Mental workload is mostly defined as the ratio between the task demands and the capacity of the operator (e.g. Kantowitz, 1988; O'Donnell & Eggemeier, 1986). Under conditions of high workload considerable effort is needed to perform a task adequately. In contrast, under conditions of low workload, there is no relation between task load and effort.

Techniques for measuring mental workload can be divided into performance measures, subjective ratings and physiological measures. In a complex task environment it is often not possible to use performance measures as an index of workload. In many instances it is not possible to obtain performance measures for each subtask; there are also no generally agreed procedures to combine these scores into a total score reflecting overall performance. Furthermore, it is often difficult to know which task is critical at a particular moment. Another complicating factor is that operators will try to keep their performance at an acceptable level. Operators adapt to increasing task demands by exerting additional effort to maintain a constant level of performance. The level of performance, therefore, only provides valuable information when other techniques are used to index the invested effort.

Rating scales generally provide a good indication of the overall workload. In many instances, however, operators may not have sufficient time to fill out a rating scale while they are working. Moreover, operators appear not to be able to discriminate between the demands of the task and the effort invested in task performance. In other words, on the basis of rating scales it is not clear whether an operator works hard or thinks that he has to work hard.

When the task demand is high, operators have to invest more energy by mental effort in order to maintain an adequate level of performance (Hockey, 1986; Gaillard & Wientjes, 1994). Such effort results in a decrease in parasympathetic and an increase in sympathetic activity (Mulder & Mulder, 1987; Gawron, Schiflett & Miller, 1989), which results in peripheral reactions in heart rate, respiration, and blood pressure. Since these variables are also influenced by other factors, such as physical activity, an estimate of workload should be based on several measures. The advantage of physiological measures is that they are unobtrusive and objective, and provide continuous information about mental effort.

Techniques to evaluate mental workload should measure the amount of effort invested in a task. Since effort cannot be measured directly, a criterion has to be used. In this experiment the validity of the different measurement techniques was investigated with task load as the criterion. There is, however, only a direct relation between task load and effort when the following criteria are met:

- The task has to be so demanding that it approaches the maximum capacity of the operator.
- The subjects must not give up too easily because the task is too demanding.
- The subjects have to be motivated, so that they are investing more effort in the task as the task becomes more demanding.

In the present experiment two rating scales and several physiological measures were evaluated. A unidimensional (BSMI; Zijlstra, 1993) and a multidimensional rating scale were compared. Both rating scales have proven to be good measures of mental workload (BSMI: Zijlstra, 1993; TLX: Hart et al., 1988; Hill et al., 1992). The physiological measures were: Heart rate (HR), systolic and diastolic blood pressure (BP) from beat to beat, respiration and saliva cortisol.

The experiment has been conducted under contract with the Netherlands Royal Air Force and is the first in a series of experiments that has to result in a set of measurement techniques that can be used in fighter jets. For this experiment we have used a part-task flight simulator (fixed base).

Method

Subjects

Ten male students of the Royal Military Academy participated in the experiment. All subjects had some flight training (less than 100 hours). They were all preparing to go to the USA within a year after the experiment to become an F16 jet pilot. The students were between 21 and 24 years old.

Simulator

The simulator consisted of two computer monitors, a throttle and a stick. The host monitor was positioned in front of the subject. On this monitor the environment was presented. Tactical information was presented on the second monitor which was located on the right side of the central monitor.

The flight characteristics were similar to an F16 fighter jet. Horizontal and vertical movements were made by a force stick. The power of the engine was manipulated by a throttle. For extra power an afterburner could be used by pulling a handle with the left fingers and pushing the throttle to the end position. Spoilers could be used if the speed had to be decreased fast. These spoilers were controlled by the left thump and could be set in 0 , 30 , or 60 positions. Information about the state of the jet was presented via a Head Up Display (HUD). On the stick was a button for shooting missiles that could be pressed by the right thump. The second monitor presented tactical information depending on the scenario that had to be flown.

Scenarios

Subjects had to fly two different scenarios, one with a high cognitive load (intercept) and one with a high perceptual-motor load (navigation).

In the Intercept scenario, the subjects had to intercept and follow a target jet, at a distance of 630 ft. The distance of 630 ft was reached when the centre of the engines of the target airplane (a P38 Lightning) exactly fitted within the horizon indicator in the HUD. The subjects had to use the stick and the throttle constantly because the situation was instable (there was no trim). The heading of the target airplane could be seen on the bottom of the central monitor. The exact position could be seen on the second monitor. On this monitor the own jet was presented in the centre of the screen, heading up. The position of the target airplane was presented relative to the own jet.

In this scenario a continuous memory task (CMT) was presented twice; once while flying curves and once while flying straight. This task is explained later. The duration of the intercept task was about 23 min. depending on the speed at the end of the scenario. Fig. 1 gives a schematic overview of the intercept task.

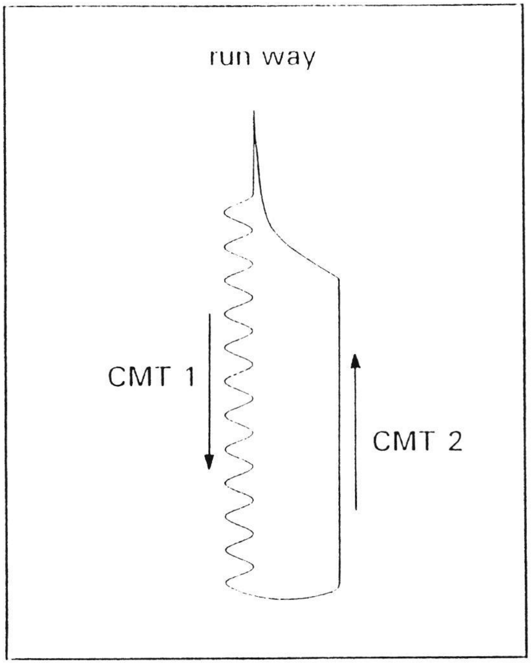

Figure 1. Overview of the intercept task. In the first segment the target airplane is flying regular curves and in the second segment it flies straight. During the first and second segment of the scenario a memory task (CMT) had to be performed.

The intercept task is divided into several segments:

1. The first 2 min. after take off when the subject is searching for the target airplane.
2. Follow the target plane:
    a. flying curves.
    b. flying curves combined with the memory task.
    c. flying straight.
    d. flying straight combined with the memory task.
3. Flying to the runway.
4. Landing (starting one minute before touch down).

Segment 2 was not the same for all subjects; the first half of the subjects was flying the curves before flying straight, while the other half did the task in reverse order. The speed of the target airplane was 473 kts during curve flying and 591 kts. during straight flying. Three seconds before the change in speed, the target airplane rotated 360 around the horizontal axis. This was a cue for the subjects to anticipate to the speed change. In the intercept scenario the task demand was determined by the difficulty of the flying task (following curves versus following straight) and by the secondary memory task.

Continuous memory task (CMT). Letters were presented by headphones in the helmet. The letters A, B, Y and Z were assigned as target letters that had to be counted in separate tallies. Whenever a target letter was presented for the third time, the subject had to press a button with the right foot and had to set the tally for that letter to zero. If a response was correct the word "correct" was presented and the word "wrong" whenever the response was incorrect or omitted. After this feedback (correct or wrong) the tally for the last letter had to be set to zero.
The duration of the CMT task was four min. In this period the target letters were presented about 24 times. The inter-stimulus interval varied between 2.5 and 3.5 s. All the letters of the alphabet were used except the letters D, H and P because they could be confused with the target letters (in Dutch). Fig. 2 presents an example of the CMT.

	TARGETS			
letters	**A**	**B**	**Y**	**Z**
f	0	0	0	0
B	0	1	0	0
w	.	.	.	.
Y	0	1	1	0
q	.	.	.	.
t	.	.	.	.
B	0	2	1	0
g	.	.	.	.
Z	0	2	1	1
k	.	.	.	.
B	0	3	1	1
s	0	0	1	1
etc.				

Figure 2. Example of the CMT task. After the presentation of a target the tally has to be increased. After the third presentation of a target the tally has to be set to zero.

In the Navigation scenario, subjects had to follow a route that was presented on the second monitor. The route had to be flown with a speed of 500 kts. and an altitude of 100 ft. There were several targets on the route that had to be attacked. Along the route were several SAM's. The range of these radars was related to the altitude of the jet and was presented by the diameter of the circles representing the radars. Subjects were told that the jet would stay out of the radar range when the jet was on the route and its altitude not above 100 ft. When the jet came inside the radar range, a warning sound could be heard and the outer part of the tactical display became red. There were three targets on the route that had to be attacked by shooting a missile.

Within this scenario several functions of a jet pilot were included. The difficulty of the flight functions was manipulated by turning angles and distance between two

successive waypoints; combat management was needed because there were several targets to be shot; threat management was needed to stay outside the range of the targets and the subjects had to navigate constantly.
The instructions to the subjects were as follows:
- Do not crash.
- Stay outside the range of the radars.
- Follow the route as close as possible.
- Keep the speed at 500 kts.
- Keep the altitude at 100 ft.
- Attack the targets.

An example of the route is presented in Fig. 3.

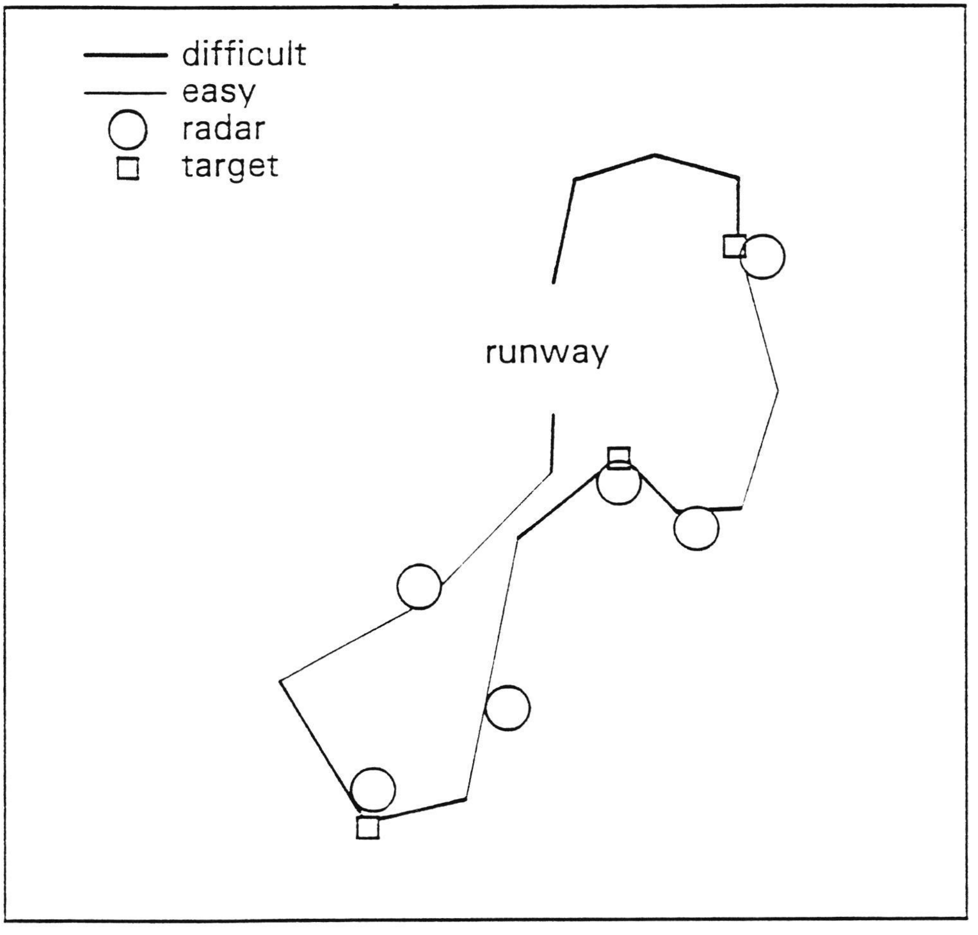

Figure 3. Example of a route that had to be followed. Difficult segments (see text) are bold. Positions of the SAM's and targets are represented by circles and squares respectively.

There were two navigation scenarios that had the same degree of difficulty. Each scenario could be divided into two segments: easy and difficult. The easy and the difficult segments of the scenario were determined by the turn angle around a waypoint, the SAM's and the position of the targets.

Workload measures

Rating scales

Two scales were used in this experiment: the NASA-TLX (Hart & Staveland, 1988) and the BSMI (Zijlstra, 1993). The TLX consists of six dimensions: mental demand, physical demand, performance, effort and frustration. The subscales have to be weighted by means of a pair-wise comparison of the subscales. These weights are used to calculate the overall workload score.

The BSMI is a unidimensional rating scale that asks for the amount of effort that has been invested during task performance. Subjects have to respond by putting a marker on a vertical axis that ranges from 0 to 150. On the right side of the scale are statements like "not at all effortful", "a little effortful", very effortful" etc. Subject gave their ratings directly after finishing the flight. The six subsales of the TLX were rated on a computer with a mouse. The BSMI was rated with paper and pencil.

The weights of the TLX were obtained at the end of the training sessions. Subjects were asked to compare all subscales for all segments of the scenarios. Most subjects however indicated that there was no difference between the segments of the scenario regarding the importance for the overall workload. So weights were calculated only once.

Physiological measures

Several physiological signals were recorded during task performance. The electrocardiogram (ECG) was digitized with a 100-Hz sample frequency. Inter-Beat Intervals (IBI) were calculated from successive R-peaks in the ECG signal.
The Heart Rate Variability (HRV) spectrum can be divided into three regions (Mulder, 1988):

low-band: 0.02-0.06 Hz
mid-band: 0.07-0.14 Hz (0.10 Hz component)
high-band: 0.15-0.40 Hz

The mid band region has been found to be the most sensitive to changes in mental effort (Aasman, Mulder & Mulder, 1987; Mulder, 1992; Veltman, 1989). The spectral energy in this region decreases when the mental effort increases. In this experiment the energy in the mid band region of the HR spectrum has been calculated and this will be referred to as HRV in this paper.

HRV was calculated with the computer program Carspan (Mulder, 1988). The program was instructed to calculate the power in the mid band within a time window of 40 s which is moved in steps of 10 s. Thus HR variability was calculated for every 10 s.

Blood pressure (BP) was recorded continuously via a non-invasive TNO Finapress tonometer. A cuff was placed around the finger that compresses the veins in a such way that just a little blood is coming through. The pressure inside the cuff follows the pressure inside the finger rather quickly (100 Hz). The BP was derived from the pressure inside the cuff. The apparatus detects the maxima and minima of the pressure signal that correspond to the systolic and diastolic BP respectively. The cuff was placed around the right mid finger, because this finger stayed at a constant height during the experiment and it was not necessary to bend this finger during task performance. The right hand was positioned below the heart. Because this version of the tonometer did not correct for the position of the cuff related to the heart, the absolute BP values were too high. In this experiment, this did not pose a problem, because the interest was in changes in BP within subjects, rather than the absolute BP. The signals of the systolic and diastolic BP were digitally recorded with a 25-Hz sample frequency.

Respiration was recorded by means of inductive plethysmography (Respitrace, Inc.) which works with two bands. One band was placed around the chest and the other around the abdomen. The stretching of these bands due to the expansion of the chest and abdomen was recorded. Before each task session, the respiratory system was calibrated (cf. Wientjes, 1992). Subjects had to breathe during one minute via a spirometer which measures the respiratory volume. The volume signal was recorded simultaneously with the other two signals. A regression formula was determined on these three signals that was used to transform the chest and abdomen signals into a volume signal. Several parameters of this signal were derived by the computer program Highlow (Wientjes, 1992). The two respiratory signals were digitally recorded with a sample frequency of 25 Hz.

Several parameters can be distracted from a respiratory signal (Wientjes, 1992). In this experiment the following parameters were calculated:

- Respiration Rate (RR)(min^{-1}): number of respiratory cycles per minute.
- Tidal Volume (VT)(ml): amplitude of the respiratory signal.
- Inspiratory Flow (IF)(ml/s): VT/(inspiratory time).
- Duty Cycle Time (DCT): (inspiratory time)/(total cycle time).
- Minute Volume (MV)(ml): RR X VT

Cortisol has been obtained from saliva and has been analysed by radioimmunoassays (Farmos cortisol [^{125}I] kit). Cortisol was measured during the training day each hour between 13.00 and 15.00. During the experimental day, cortisol was measured before and after each scenario (7 times total). The saliva was obtained by means of small pieces of cotton wood (Sarstedt salivettes), held in the mouth by the subjects, for about 30 s.

Baseline measures
Baseline measures for the physiological parameters were conducted during the first day between 14.00 and 15.30 hours. Subjects were asked to relax for about 20 minutes while they were sitting in the simulator. The mean values for the last 10 minutes were used as a baseline.

Performance measures
Intercept task. The following measures were distracted:
- deviation from 630 ft / follow distance
- standard deviation of mean distance.
- percentage of time that the subject actually followed the target airplane. The criterion was that the target airplane had to be on the screen and the distance to that airplane had to be 2000 ft or smaller.

Mean values were calculated for each segment.

CMT. For the CMT-task, the mean reaction time and the percentage correct responses were determined.

Navigation task. The position of the jet was compared to the route to calculate:
- distance from the route
- altitude
- speed

Mean values were calculated for the easy and difficult segments separately.

Procedure
The subjects were tested in couples. They spent 1.5 days to train the tasks properly. The experiment was conducted on the second afternoon. Each subject trained the intercept task four times; the first two times without the CMT-task. The intercept task that had to be trained was the same as the task that had to be performed during the experiment. The navigation task was trained five times with other scenarios than during the experiment. The subjects performed the task as is shown by Table I.

Table I. Time schedule of the experiment.

time	subject 1	subject 2
13.00	intercept	break
13.45	break	intercept
14.30	navigation	break
14.45	navigation	break
15.00	break	navigation
15.15	break	navigation
15.30	intercept	break
16.15	break	intercept
17.00	end	end

Two factors were manipulated in the intercept scenario and one in the navigation scenario. These factors will be referred to as:

- curves/straight: difference between flying curves and flying straight in the intercept scenario.
- CMT: difference between flying without and with the CMT in the intercept scenario.
- easy/difficult: difference between the easy and difficult segments of the navigation scenario.

Results

Performance

Intercept task. The results of the performance data are presented in Table II.

Table II Performance results in the intercept task (deviation from required distance of 630 ft, standard deviation and % of time correct following).

	curves	curves &CMT	straight	straight & CMT
deviation	304	333	418	338
SD	270	286	217	211
% correct	86	81	88	97

Subjects were not able to maintain the mean distance to the target airplane at 630 ft. On the average they flew too far behind the target airplane. The differences in distance between the four segments were not significant. The variability in distances was large as is clear from the standard deviation. During the straight segments, the standard deviations are smaller than during the curves [$F(1,9)=8.9$, $p<0.05$]. The % correct was smaller during the curves than during the straight segments [$F(1,9)=9.4$, $p<0.5$]. During the curves the addition of the CMT resulted in a reduction of the % correct and during the straight segment the CMT increased the % correct [$F(1,9)=29.1$, $p<0.01$].
In summary: during the straight segment the target airplane disappeared from the screen less often and the distance to the target airplane was more constant. The CMT task caused a decrease in flight performance during the curved segment while it enhanced the performance during the straight segment.

CMT-task. In the CMT task, the reaction times and the percentage of correct responses were determined. The results are presented in Table III.
The reaction times were significantly longer during curves than during the straight segments [$F(1,9)=7.1$, $p<0.05$]. The percentage of correct responses was almost the same.

Table III. Performance results for the CMT task.

	CURVES	STRAIGHT
reaction times (s)	1.11	0.98
% correct	77	75

Navigation task. During the navigation task the deviations from the route, altitude and speed were determined. Mean values were calculated for the easy and difficult segments of the scenario and are presented in Table IV. The results of one subject are not included in the overall means, because he missed several waypoints. Therefore no information was available about the part of the route he was flying on.

Table IV. Performance during the navigation task for the difficult and easy segments of the scenario separately.

	deviation (miles)		altitude (ft)		speed (kts)	
	mean	SD	mean	SD	mean	SD
difficult	0.30	0.18	185	71	503	11
easy	0.15	0.10	131	42	500	18

The deviation from the route during the difficult segments of the scenario was twice as large as the deviation during the easy segments [$F(1,8)=14.8$, $p<0.01$]. The variation in deviation (SD) was also much larger during the difficult segments [$F(1,8)=9.5$, $p<0.05$]. Altitude was higher than 100 ft in both segments but was highest at the difficult segments [$F(1,8)=15.4$, $p<0.01$]. The variations in altitude (SD) were also larger during the difficult segments [$F(1,8)=5.5$, $p<0.05$]. The mean speed and variations in speed did not differ significantly between the two segments of the scenario.

The differences in performance between the easy and difficult segments were due to the fact that turning angles were larger during the difficult segments. During large turns, the lift of the jet becomes smaller which has to be compensated by putting the nose up. Otherwise, the jet would crash almost immediately. When attempting to prevent a crash, subjects tend to overcompensate for the decrease in altitude. The greater deviation from the route during the difficult parts was largely caused by this phenomenon. During bendings, subjects did not look at the tactical display where the deviation from the route was presented. They were too much concentrated on the central display where the information about the state of the jet was presented. The bendings did not change the speed of the jet. That explains why the speed was not different in the two segments.

Rating scales

Subjects were asked to rate the workload for each segment of the scenario after the task performance. The results of the intercept task are presented in Table V.

Table V. BSMI and TLX scores for each segment of the intercept task.

	curves	curves & CMT	straight	straight & CMT
BSMI	52.6	76.5	39.7	69.7
TLX	39.8	55.2	35.5	53.6

The segments with the CMT task were rated significantly higher than the other segments; BSMI: [$F(1/9)=22.1$, $p<0.01$], TLX: [$F(1/9)=13.7$, $p<0.01$]. The difference between flying curves and flying straight was only significant for the ratings on the BSMI; [$F(1/9)=5.3$, $p<0.05$].

The correlations between the scores on the BSMI and the scores on the subscales of the TLX are presented in Table VI. The correlations were calculated after the scores for each subject were transformed to a Z-score. This was done to eliminate the effects of baseline scores. The correlations were calculated for 140 scores; 10 subjects × 7 segments × 2 repetitions. The intercept task yielded 5 scores: curves, curves & CMT, straight, straight & CMT and landing. The navigation task yielded 2 scores: the whole scenario and landing. All correlations in Table VI differ significantly from chance level ($p< 0.01$). It is remarkable that the TLX "effort" scale correlated relatively poorly with the BSMI scores although both scales ask for the same aspect.

Table VI. Correlations between BSMI-scores and TLX-scores.

Subscales TLX	BSMI
mental demands	0.59
physical demands	0.28
time pressure	0.40
performance	0.72
effort	0.40
frustration	0.40
overall workload (TLX)	0.61

Physiological measures

The results of the physiological measures were analysed separately for each segment and for each scenario. For the intercept task these results are presented in Table VII and the results of the navigation task in Table VIII.

Table VII. Physiological results for each segment of the intercept task.

	baseline	curves & cmt	curves	straight & cmt	straight
IBI	922	720	668	724	684
HRV	2000	1494	1149	1695	1281
Syst. BP	135	166	170	169	173
RR	17.6	21.6	21.9	21.1	21.4
VT	445	675	710	650	679
IF	418	695	714	663	684
DCT	30.3	34.3	35.5	33.6	34.6
MV	7595	14244	15187	13339	14149

The values for all segments differ significantly from the baseline values ($p<0.01$). The CMT task yielded significant differences for: IBI [$F(1/9)=65.5$, $p<0.01$], HRV [$F(1/9)=5.7$, $p<0.05$], systolic BP [$F(1/9)=5.9$, $p<0.05$], duty-cycle time [$F(1/9)=13.2$, $p<0.01$] and minute volume [$F(1/9)=5.9$, $p<0.05$]. Only the duty-cycle time and minute volume yielded significant differences between flying curves and flying straight: [$F(1/9)=5.6$, $p<0.05$] and [$F(1/9)=6.9$, $p<0.05$] respectively.

Table VIII. Physiological results for the baseline and easy and difficult segments of the navigation task.

	baseline	easy	difficult
IBI	922	727	699
HRV	2000	1685	1333
Syst. BP	135	163	161
RR	7.6	22.6	24.0
VT	445	622	652
IF	418	679	742
DCT	30.3	33.6	34.8
MV	7595	13718	15522

All values differ significantly from the baseline values ($p<0.01$). The values from the easy segments differ significantly from the values in the difficult segments except for systolic BP. All changes are in the expected direction.
For a better reading, the values of Tables VII and VIII are presented graphically in figure 4. The values are presented as percentage change from the baseline.

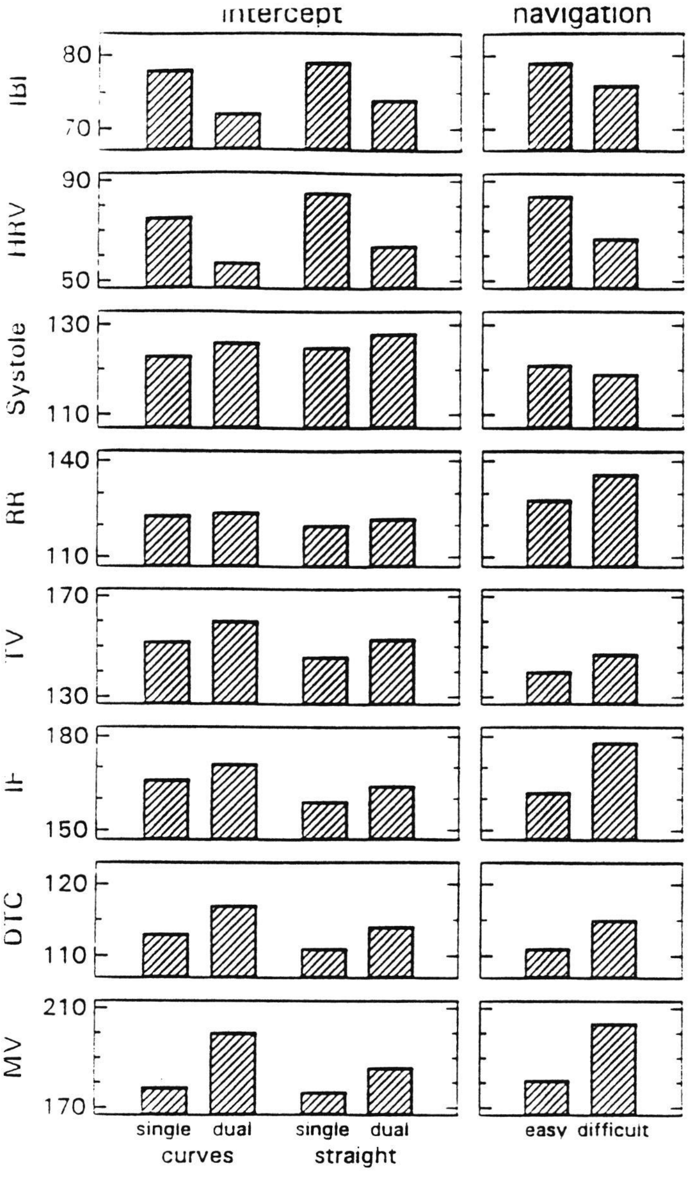

Figure 4. Physiological reactions for all segments of the intercept and navigation scenario. Results are presented as percentage change from the baseline. (single: no CMT, dual: CMT).

The results in all preceding tables are based on mean values within segments of the scenarios. The advantage of physiological measures compared with subjective ratings is that they can provide continuous rather than discrete information about mental effort. Fig. 5 gives an example of the results of HRV during the intercept task for one subject. It can be seen that the HRV decreases whenever the subject performs the CMT task and when the subject is busy to land.

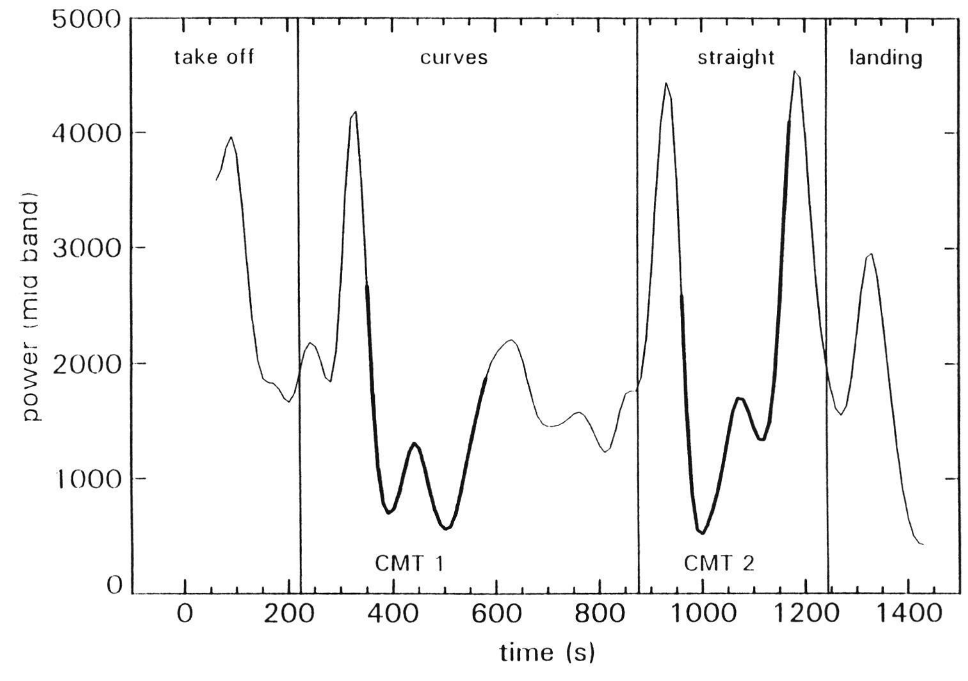

Figure 5. Time series of heart-rate variability for one subject performing the intercept task.

The time series of HRV during the navigation task for the same subject is presented in Fig. 6. It can be seen that the HRV decreases just before the subject flies over the targets. At these moments the subject is preparing to attack the targets, which is very effortful. At the end of the scenario HRV decreases again which is caused by the landing that is also quite effortful.

The coherence between HR and respiration in the mid-band of the frequency spectrum was rather low (0.3) compared to the coherence in the high band (0.7) and was not different for the experimental conditions. Thus the observed changes in HRV due to task load are not directly related to changes in respiratory frequency.

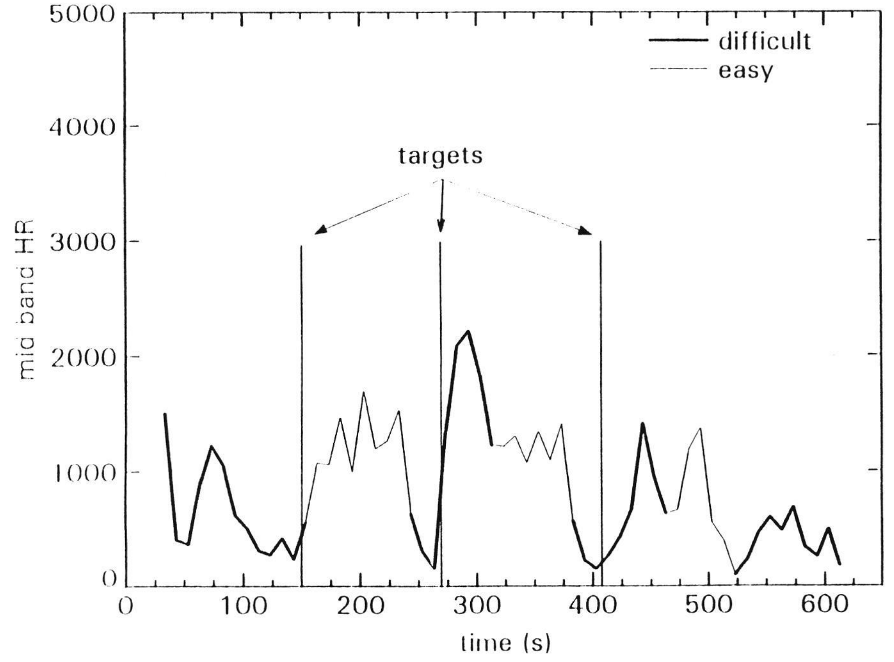

Figure 6. Time series of heart-rate variability for one subject during the performance of the navigation task (the same subject as the subject in figure 5).

Relation between variables

For a comparison between the subjective and physiological techniques, correlations were calculated. This was only done for the intercept task because in this scenario subjects rated the workload for all segments. The results are presented in Table IX. The correlations are based on 80 values (10 subjects × 4 segments × 2 repetitions).

Table IX. Correlation between subjective ratings and physiological measures.

	BSMI	TLX
IBI	-0.46**	-0.28**
HRV	-0.37**	-0.19
Syst. BP	0.38**	0.17
RR	0.27 *	0.12
VT	0.12	0.08
IF	0.18	0.10
DCT	0.32**	0.29**
MV	0.25 *	0.19

* $p<0.05$
** $p<0.01$

Cortisol

The average cortisol level on the training day was 10.2 and during the experimental day 12.3 [$F(1,9)=4.32$, $p=0.07$]. The mean values do not differ significantly because one subject had a lower cortisol level on the experimental day. When this subject was excluded from the analysis, the difference between training day and experimental day became highly significant (respectively 9.3 and 12.4, [$F(1,8)=17.7$, $p=0.003$]. During the experimental day, the post-task levels did not differ significantly from the pre-task levels.

There were some interesting correlations between cortisol levels and performance that are presented in Table X.

Table X. Correlation between mean cortisol levels on the training day and performance.

	Cortisol
Intercept task:	
distance from target airplane	0.73*
RT on CMT	-0.05
% correct responses on CMT	0.10
Navigation task:	
Deviation from route	-0.27
altitude	0.05
mean landing score	-0.72*

* : $p < 0.05$

The correlation between mean cortisol levels on the training day and cortisol levels on the experimental day is 0.75 ($p=0.13$). Again, when the subject with the lower cortisol levels on the experimental day is excluded, the correlation is 0.97 ($p<0.01$). Correlations between performance and cortisol on the experimental day are almost identical to the correlations in table X when this subject is excluded.

Discussion

With increasing task demands, subjects will only invest more effort when they are sufficiently motivated. Although this was not tested explicitly, we are certain that our subjects were well motivated. Most subjects asked to fly a scenario again at the end of the experiment because they found the task enjoyable. Furthermore, the subjects were paid for their participation and the performance was observed by a second subject who was a colleague. Therefore, task load can be regarded as a valid criterion in this experiment.

In the present study, a measure is considered to be valid when it discriminates between easy and difficult segments of the scenarios. Difficulty was manipulated in two scenarios. In the intercept scenario, mental workload was examined as a function of flying curves or straight, and addition of a secondary task. In the navigation scenario, the physiological reactions to easy and difficult segments of the scenario are examined.

A summary of the results is presented in Table XI. The results are discussed separately for the rating scales, physiological variables and cortisol.

Table XI Significant changes of variables for each experimental factor.

	curves	CMT	easy/difficult
Rating scales:			
BSMI	■	■	(not measured)
TLX	□	■	(not measured)
Physiology:			
IBI	■	■	□
HRV	□	■	■
BP	■	□	□
RR	■	□	□
VT	■	□	□
IF	■	□	□
DCT	■	■	■
MV	■	■	■

■ : $p < 0.05$

Rating scales

The TLX was less sensitive than the BSMI, because it did not differentiate between curves and straight and was less sensitive to the CMT. The BSMI also correlated better with the physiological parameters. An explanation for this might be that subjects were confused by the subscales of the TLX. One would expect a strong correlation between the effort subscale and the BSMI. The BSMI correlated, however, stronger with the subscale for "mental demand" (0.59) than with "mental effort" (0.40). Possible, the mental demand subscale was interpreted by some subjects as mental effort; after a rating was given on this subscale the latter subscale may have caused confusion. Subjects might have rated this subscale quite randomly because they did not want to rate both subscales in the same way. Confusion of the subscales may have caused an increase in variation, which leads to a reduction in sensitivity. Compared to the BSMI, the TLX requires more time because of the weighting procedure and the extensive instructions before the start of the experiment. Additional instructions would make the TLX hardly useful in practical situations.

Another problem with the TLX was the subscale "frustration" which was translated by the Dutch word "frustratie". Although this translation is correct according to the dictionary, the Dutch word has a more negative connotation. Most subjects rated this subscale always with a "0", because a "fighter pilot is never frustrated". Therefore, the results of the TLX cannot be compared with results from experiments in the USA (Hart et al., 1988), at least with respect to this aspect. The TLX should be validated to the Dutch language to find proper translations of the subscales. On the other hand, when one needs a Dutch workload scale, the present results show that the BSMI is a rather good one. The BSMI can be filled out quickly, and does not require a long time for instructions.

Physiological measures

All physiological indices during task performance differed from baseline values. This is not surprising because subjects were more activated during task performance, even when the task was easy. The changes within the task are more important to establish the validity. In particular, it is more important that physiological indices reflect the changes in mental load as a function of changes in task load.

Although the physical load was very low in this experiment it cannot be neglected in describing the results of the physiological variables. During the curves in the intercept scenario more stick input is required than in the straight segments. This is also the case for the difficult as compared to the easy segments in the navigation scenario. Thus, effects due to the factors curves/straight and easy/difficult may be confounded by physical load. Only the effect of adding the CMT can be ascribed to mental effort.

IBI and HRV both were sensitive for the factors CMT and easy/difficult; the more demanding the task, the lower the IBI and HRV. Both indices can be used for mental workload studies although they do not provide the same kind of information. Since HRV appears to be less sensitive to physical demands (Lee & Park, 1990), it may give more information about the mental workload in practical situations where physical activity may play a role.
We have analysed the IBI data with a computer program that made it possible to look at changes in HRV within small time windows. It appeared that the HRV is very dynamic over time. Even in the baseline condition, the HRV values changed very rapidly and ranged from 100 to 10.000. For this reason a time plot of HRV data cannot be interpreted straightforward in a way that low values always correspond to high effort and high values always correspond to low effort. The mean values are lower during periods of high effort, but there are still high values of HRV within these periods. The fluctuation in HRV depends on the length of the time-window for frequency analysis. A long window results in more stable HRV values but the analysis becomes less sensitive to fast changes in effort and more sensitive to non-stationary part of an IBI-signal. In the present experiment, a time window of 40 s was chosen that was shifted in steps of 10 s. This window might have been too short. More data are needed to find the best time window and interpret the time series of HRV adequately.

Of the respiratory parameters, the duty-cycle time appeared to be most sensitive. This index was affected by all factors. Although minute volume was also affected by all factors, it was less sensitive than the duty-cycle time. All respiratory parameters were sensitive for the factor easy/difficult. Respiration is controlled by two central mechanisms; a drive mechanism indexed by inspiratory flow and a timing mechanism indexed by the duty-cycle time. The results from this experiment show that mental load has its strongest influence on the timing mechanism because the duty-cycle time was the only parameter that was influenced by the CMT. The easy/difficult factor that is confounded with physical load had its strongest effect on the inspiratory flow. The activity of both mechanisms are influenced by physical and mental load (Wientjes, 1992). It seems, however, that mental load has a stronger influence on the timing mechanism. The duty-cycle time is defined by the inspiration time divided by the total cycle time. A change in duty-cycle time can have many causes. Further analysis showed that the increase in duty-cycle time was caused by a decrease in expiratory pause. In other words when subjects were investing more effort in the task the inspiratory period started earlier.

In the present study, physiological results differentiated nicely between the experimental conditions. In several other experiments however, physiological variables were less sensitive. In an overview of studies of pilot workload (Veltman, 1991), physiological variables were shown to discriminate between easy and difficult segments, only during real flight, but not in a simulator. In an overview of HRV studies Jorna (1992) showed that in general changes in task conditions were not confirmed by changes in HRV, although changes between baseline and task were mostly noticeable. A possible explanation is that changes in physiological parameters only are found when subjects are willing to invest extra effort. In the pilot workload studies, the subjects in the simulator were experienced pilots who possibly were not willing to spend as much effort as they would do in real flights. As explained earlier, the subjects in the present study were highly motivated, which could be an explanation for the positive results.

Subjective ratings are almost always sensitive to changes in task load in the simulator as well as during real flight. This indicates that subjective ratings are reflecting changes in task load rather than changes in effort. Thus, subjective and physiological techniques do not give the same kind of information and are therefore both important for mental workload studies.

Cortisol levels at the end of the tasks were not higher than the pre-task levels, which suggests that the tasks could not be considered as stressful. However, there was a relationship between cortisol and overall performance. Subjects with high levels of cortisol had a poor performance in the intercept task and performed worse during landing. In the navigation scenario cortisol did not correlate with performance. This could be due to the fact that subjects were able to choose easier strategies in the intercept scenario and during landing, but not in the navigation scenario. Following the target airplane in the intercept scenario became much easier when the distance between the two airplanes increased. Landing also became easier when subjects ignored the landing requirements, and concentrated on a "safe" landing. In the navigation scenario on the other hand, a choice to increase the altitude was almost immediately punished by an irritating sound, indicating that one was flying into the range of an enemy radar. The same holds for deviations from the route. Thus, subjects were prevented from adopting easier strategies. These findings are compatible with those ofVærnes et al. (1989), who found that F16 pilots with higher levels of cortisol had a poor landing performance. Since these findings have been obtained among a very homogeneous population (subjects who met the same selection requirements to become a fighter jet pilot), the relation between cortisol and performance seems to be quite robust. Ursin et al. (1978) found a relation between cortisol level and a defensive personality structure, which might also explain the present result. Whenever a subject is more defensive, he will choose an easier strategy.

The two subjects with the best performance scores showed a low cortisol level before the task and a small increase afterwards. Their physiological data also showed very adaptive profiles during periods of high demand: the HRV and IBI decreased immediately and recovered very soon after the task became less demanding. It appears that a fast physiological adaptation to task demands is positively related to performance.

Conclusions

- The BSMI is a simple rating scale that produces better results than the TLX. The BSMI is more sensitive and is much easier to use.
- From the cardiovascular parameters, the IBI and HRV both are valid measurement techniques for mental workload.
- HRV obtained by means of frequency analysis with a moving window seems a promising method to give information about the changes in mental effort within small time periods.
- From the respiratory parameters the duty-cycle time is the most sensitive.
- Subjects with high levels of cortisol perform poorly, possibly due to a defensive task strategy.

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