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Age, Experience and Automation in European Air Traffic Control

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Abstract

This report is concerned with the relation of age, experience and automation. It has been prepared as part of the 'Solutions for the Human-Automation Partnerships in European ATM (SHAPE)' Project managed by the ATM Human Resources Unit of EUROCONTROL, later renamed the Human Factors and Manpower Unit (DIS/HUM) and today known as the Human Factors Management Business Division (DAS/HUM). This is the first report of the SHAPE Work Package 'Age and Experience'.

The document contains a literature review about known positive and negative effects of ageing on human performance, and discusses the relevance of these aspects for the European Air Traffic Management (ATM) environment. The results were discussed with Air Traffic Controllers (ATCOs) and summarised.

A sequel document (currently under preparation) is dealing with the application and evaluation of a questionnaire about the effect of age and experience, which was distributed to EUROCONTROL Member States and evaluated in 2002.

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Contact Persons	Tel	Unit
Oliver STRAETER, SHAPE Project Leader	+32 2 7295054	Human Factors Management Business Division (DAS/HUM)
Michiel WOLDRING, Manager, HRS Human Factors Sub-Programme (HSP)	+32 2 7293566	Human Factors Management Business Division (DAS/HUM)

Author

J. Rothaug

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EATMP Infocentre
EUROCONTROL Headquarters
96 Rue de la Fusée
B-1130 BRUSSELS

Tel: +32 (0)2 729 51 51
Fax: +32 (0)2 729 99 84
E-mail: eatmp.infocentre@eurocontrol.int

Open on 08:00 - 15:00 UTC from Monday to Thursday, incl.

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The following table identifies all management authorities who have successively approved the present issue of this document.

AUTHORITY	NAME AND SIGNATURE	DATE
Please make sure that the EATMP Infocentre Reference is present on page ii.		
SHAPE Project Leader	O. STRAETER	18. 8. 2003
Chairman HRT Human Factors Focus Group (HFFG)	V.S.M. WOLDRING	25. 8. 2003
Manager EATM Human Resources Programme (HRS-PM)	M. BARBARINO	25. 08. 2003
Chairman EATM Human Resources Team (HRT)	A. SKONIEZKI	25. 8. 2003
Senior Director EATM Service Business Unit (SDE)	W. PHILIPP	25.08.03

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CONTENTS

EXECUTIVE SUMMARY

This report is concerned with the relation of age, experience and automation. It is the first report of the Work Package 'Age and Experience' of the project entitled 'Solutions for the Human-Automation Partnerships in European ATM (SHAPE)', which is managed by the ATM Human Resources Unit of EUROCONTROL, later renamed the Human Factors and Manpower Unit (DIS/HUM) and today known as the Human Factors Management Business Division (DAS/HUM).

The document contains a literature review about known positive and negative effects of ageing on human performance, and discusses the relevance of these aspects for the European Air Traffic Management (ATM) environment. It also provides a summary of interviews with Air Traffic Controllers (ATCOs) on this topic.

A second document (currently under preparation) is dealing with the application and evaluation of a questionnaire about the effect of age and experience. The questionnaire was distributed and evaluated in 2002, and provides a view of the controllers of European Air Traffic Control Centres (ATCCs) on their perception of the positive and negative sides of age and experience.

Section 1, 'Introduction', outlines the background to the project, and the objectives and scope of the report.

Section 2, 'Ageing', provides a definition of ageing, and points out the relevance of ageing to European ATM.

Section 3, 'What do we Know about the Ageing Process and Mental Performance?', gives an overview of the research findings on age and mental performance, and on age and job performance. Furthermore, it summarises a number of studies conducted on age and job performance of ATCOs.

Section 4, 'Age and Shift Work', explores the interaction of processes and shift work. It reviews the consequences of shift work on health and well-being.

Section 5, 'Age and Career Development', stresses the importance of personnel and career development in European Air Traffic Control (ATC). In this section the link of the subject to ageing is displayed, and the demand for action in this area is pointed out.

Section 6, 'Age and Automation', reviews the issues relevant with regard to ageing employees and technological change. Little research has been conducted in this area; however, some aspects of technical system transition are of importance and, as such, should be carefully considered in the future.

Section 7, 'How do Controllers See the Issue', summarises an interview study conducted by DIS/HUM (today known as DAS/HUM). 76 European controllers were interviewed on the issue of ageing in ATM. The results give to a great extent a confirmation of research findings from other areas.

Section 8, ‘Perspectives for the Future – What Needs to be Done?’, concludes on areas of further work associated with ageing. It describes necessary actions to tackle the problems revealed in earlier sections of this document.

References, Further Reading, a list of the Abbreviations and Acronyms used in this document and their full designations, and Acknowledgements are also provided.

1. INTRODUCTION

1.1 Purpose

The purpose of this document is to provide information on an issue concerning all of us: ageing.

The questions related to controllers growing older on the job, who at the same time have to face significant traffic increases and major procedural and technical changes, are tackled.

The report reviews relevant literature in this area to examine the psychological background of mental ageing, its impacts on job performance and the interaction with professional experience. The last section of the document provides a summary of interviews with air traffic controllers, who had been asked about their view on the issue.

1.2 Scope

This document will focus on those aspects of ageing which are relevant for people at work. It will not address issues associated with retirement or aspects of very old age. The main emphasis is on the interaction of age and experience and their consequences for job performance of air traffic controllers. Furthermore, it addresses the issues of shift work, career development, and automation. A list of the reviewed literature is provided in the Annex 'References'.

In order to get the opinion of operational staff on the issue, 76 controllers, all of them over forty years of age, in six European Area Control Centres (ACCs) were interviewed. A representative sample of five European countries (Hungary, The Netherlands, Portugal, Sweden and the United Kingdom) participated in this explorative interview study.

1.3 Background

The work on age, experience and automation in European ATM presented in this module is embedded in a larger project called 'Solutions for Human-Automation Partnerships in European ATM (SHAPE). The SHAPE Project started in 2000 within the Human Factors Sub-Programme (HSP) of the EATMP Human Resources Programme (HRS) conducted by the ATM Human Resources Unit of EUROCONTROL, later renamed 'Human Factors and Manpower Unit (DIS/HUM)', and today known as 'Human Factors Management Business Division (DAS/HUM)' (see EATMP, 2000a).

SHAPE is dealing with a range of issues raised by the increasing automation in European ATM. Automation can bring success or failure, depending on

whether it suits the controller. Experience in the introduction of automation into cockpits has shown that, if human factors are not properly considered, 'automation-assisted accidents' may be the end result.

Seven main interacting factors have been identified in SHAPE that need to be addressed in order to ensure harmonisation between automated support and the controller:

- Trust: The use of automated tools will depend on the controllers' trust. Trust is a result of many factors such as reliability of the system and transparency of the functions. Neither mistrust nor complacency are desirable. Within SHAPE guidelines were developed to maintain a correctly calibrated level of trust (see EATMP, 2003a, 2003b, 2003c).

- Situation Awareness (SA): Automation is likely to have an impact on controllers SA. SHAPE developed a method to measure SA in order to ensure that new systems do not distract controllers' situation awareness of traffic too much (see EATMP, 2003d).

- Teams: Team tasks and performance will change when automated technologies are introduced (team structure and composition change, team roles are redefined, interaction and communication patterns are altered). SHAPE has developed a tool to investigate the impact of automation on the overall team performance with a new system (currently under preparation).

- Skill set requirements: Automation can lead to both skill degradation and the need for new skills. SHAPE identifies new training needs, obsolete skills, and potential for skill degradation aiming at successful transition training and design support (currently under preparation).

- Recovery from system failure: There is a need to consider how the controller will ensure safe recovery should system failures occur within an automated system (currently under preparation).

- Workload: With automation human performance shifts from a physical activity to a more cognitive and perceptual activity. SHAPE is developing a measure for mental workload, in order to define whether the induced workload exceeds the overall level of workload a controller can deal with effectively (currently under preparation).

- Ageing: The age of controllers is likely to be a factor affecting the successful implementation of automation. Within SHAPE this particular factor of human performance, and its influence on controllers' performance, are investigated. The purpose of such an investigation is to use the results of it as the basis for the development of tools and guidance for supporting older controllers in successfully doing their job in new automated systems (covered by this document).

  Note that an additional report providing a questionnaire-survey throughout the Member States of EUROCONTROL is currently under preparation.

These measures and methods of SHAPE support the design of new automated systems in ATM and the definition of training needs. It also facilitates the preparation of experimental settings regarding important aspects of human performance such as potential for error recoveries or impacts of human performance on the ATM capacity.

The methods and tools developed in SHAPE will be complied in a framework in order to ease the use of this toolkit in either assessing or evaluating the impact of new systems on the controller performance, efficiency and safety. This framework will be realised as a computerised toolkit and is planned to be available end of 2003.

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2. AGEING

2.1 What do we mean when talking about 'ageing'?

The term of the 'ageing society' is well known by the media. It describes the phenomenon in the western societies which phase a formerly unknown development of their population structures. People live longer and the individual life expectancy has increased dramatically over the last decades. The death rates, especially of children, have drastically decreased, fostered by improvements in hygiene and diet. In parallel, over the last decades the birth rates have decreased. As a consequence, the relative number of older people to younger people continues to increase. Not only this development places strain on the social security systems, but it can also be regarded as one of the major challenges for our culture. Nevertheless, what has all this to do with air traffic control? We will come back to this question at the end of this section.

The way we perceive growing older depends not only on our personal experience but also on the society we live in. While in western societies old age is usually associated with deterioration and decline, in other cultural backgrounds it is given attributes like maturity, wisdom, or calmness. As the western culture tends to focus on the negative aspects of getting older, we have to overcome this 'uneasiness' in dealing with the processes related to ageing. What might help us in doing so is the fact, that there are not only downsides to growing older. The other side of the coin is the gathering of experience, knowledge and skills, and it is worth having a closer look at the interaction of those two contradictory influences.

2.1.1 Definition of ageing

Ageing is a complex mixture of factors (physiological, social, cultural factors). It is part of a natural process, starting with birth and continuing throughout life. It is also a continuing process of functional changes, associated with gain and loss in functionality. An example is the human nervous system which continuously develops throughout lifetime. Every individual is born with a certain number of brain cells, and many of these cells die during infancy already. At the same time the network which links the cells to each other is drastically growing while the child learns more and more skills (like walking, talking, etc.).

We can differentiate between several concepts of age (see Figure 1)[1]:

- Firstly, the **chronological age** (numbers of years that have elapsed since a person's birth) is for most of us identical with the concept of age.

[1] Rybash, Roodin & Santrock (1991)

- Secondly, the concept of **biological age** takes the individuals functional capacities of the vital organ system as an index for his or her present position with respect to his or her potential life span.

- Thirdly, the **psychological age** of a person is his or her ability to adapt to changing environmental demands as compared to the adaptability of other individuals of identical chronological age. It is the person's adaptive capacity in terms of learning, memory, intelligence, emotional control, motivational strength, coping styles, etc.

- Finally, the **functional age** refers to the ability of an individual to function effectively within a given environment or society.

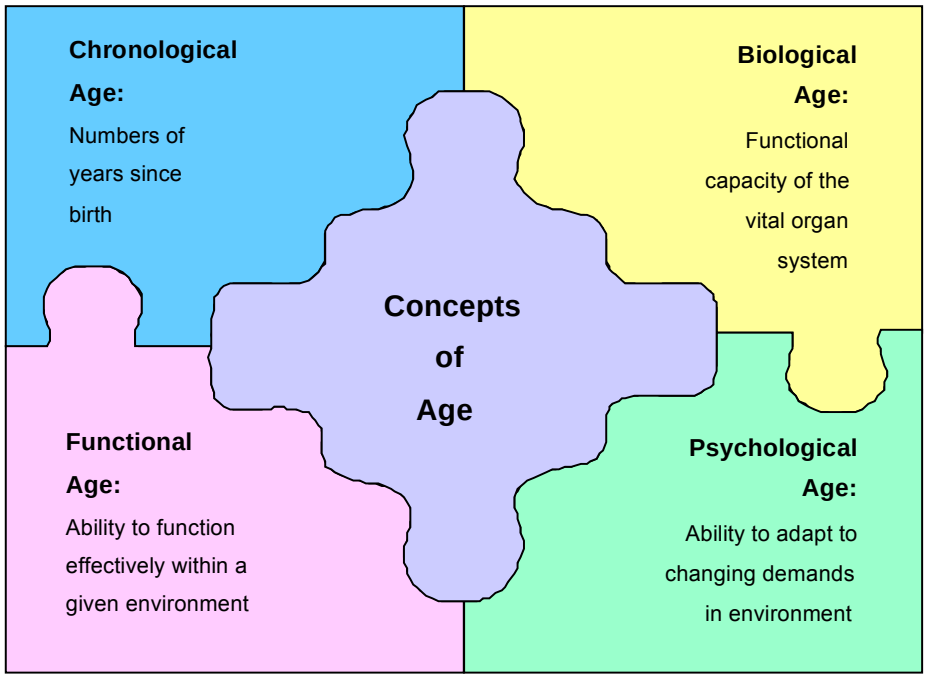

Figure 1: Concepts of age

Most take the age of 60 or 65 years to indicate the onset of old age. However, this is more a convention than a solid finding and there is always a broad variance amongst individuals regarding the manifestation of ageing. In addition, as the emphasis of this report lies on issues concerning people at work, it will take a wider age span into account, starting at the age of forty.

2.1.2 Physiological changes in the central nervous system

Most recognisable might be the physiological changes with age, for oneself and for the environment. Obviously, we look older; our vision and hearing start declining, muscular strength declines too. Less visible are the physiological changes happening to our central nervous system (i.e. in our brain). However, they are very important because the functions of our brain depend on these

processes. Our mental performance is strongly influenced by the status of our brain[2].

The human brain consists of about five thousand millions brain cells called neurons. As shown in Figure 2, these cells are linked to each other with 'wires' called dendrites, which enable them to pass on 'messages' to each other, that is they transmit electrophysiological and chemical impulses. Neurons can die, like any other body cells. However, unlike most other body cells, they cannot reproduce themselves by cell division. Instead, neurons grow new dendrites ('wires') and form new connections with each other. Those 'connective networks' can be regarded as the biological basis of mental processes. For example, they appear to be the basis for information storage in the brain; they are the physiological substratum of memory.

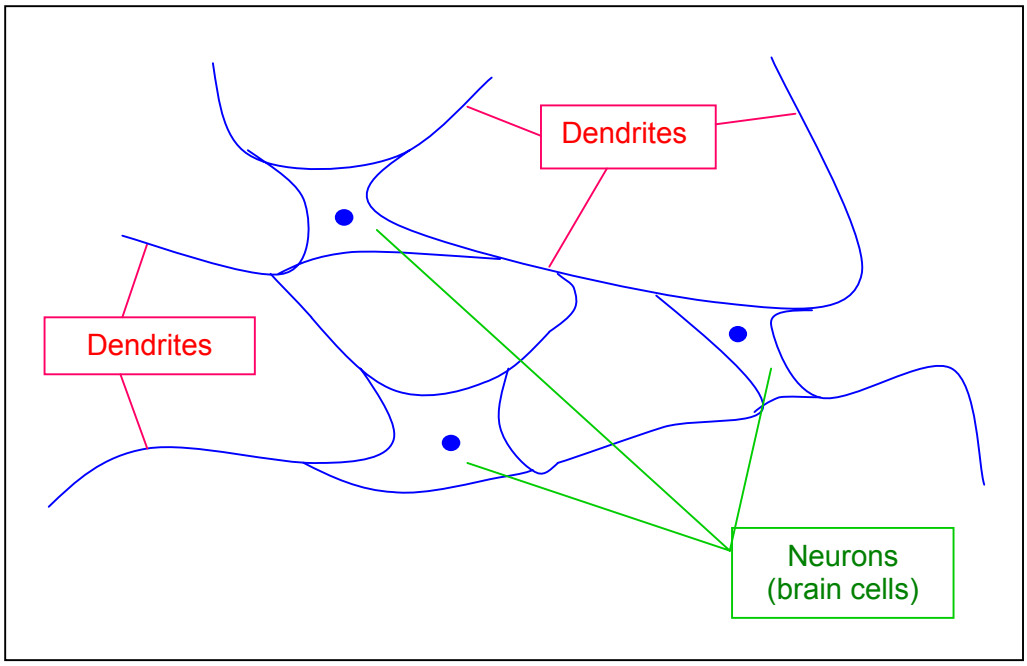

Figure 2: Schematic picture of brain cells (neurons) with dendrites

Apart from the loss of neurons a number of changes in the brain tissue are characteristic to ageing. The surviving nervous cells begin to incorporate deposits of proteins. Furthermore, the number of dendritic connections to other neurons decreases. Also some neurotransmitter systems, which are responsible for the chemical transmission of nervous impulses, show specific patterns of change. The consequence of all those physiological alterations is a decreased efficiency of the brain in the transmission of nervous impulses. If these physical ageing processes reach a certain level, mental performance will begin to suffer, e.g. we start to display memory problems[3]. Section 3 will show which effects these physiological changes can have with regard to mental performance.

[2] Rabbitt (1994); Stuart-Hamilton (1994)
[3] Craik (1994); Birren & Schaie (1985); Stuart-Hamilton (1988)

2.1.3 Ageing in ATM

But why should all of this be an issue for air traffic control? It is **becoming** more and more an issue because of increasing air traffic and major changes in technical equipment, in procedures, and in airspace organisation. These factors together put a high demand on controllers, however, the controllers above the age of forty might feel more of an impact. Cognitive abilities change with age. Even though skills suffer from impairments due to age, experience accumulated during ones working life counteract these negative effects. Research into this area has not yet concluded at what stage an air traffic controller is no longer satisfactorily operational. How can we support the older controller - with advanced design of technical systems, with adapting training methods - to keep up the required professional level as long as possible?

This module does not aim to answer those questions, more in-depth research would be required to do so. But it tries to raise awareness about the narrowing degrees of freedom available to individuals who perform a job on a daily basis which is becoming more and more demanding.

Summary

Ageing is a continuing process of functional changes, associated with gain and loss in functionality. We can make a difference between chronological, biological, psychological, and functional age. Most take the age of 60 to 65 as onset of old age. However, for this document the age range of 40 to 65 is considered as relevant.
The physiological state of our brain provides the basis for mental performance, thus the reduction of ones brain functionality leads to reduced mental capacity.

3. WHAT DO WE KNOW ABOUT THE AGEING PROCESS AND MENTAL PERFORMANCE?

The research in this area relevant to air traffic control can be divided into two broad categories. One branch is concerned with isolated aspects of cognitive performance like for example working memory, attention, or spatial visualisation. The other branch of research addresses questions of job performance.

3.1 Ageing and Mental Performance

Before going into the detail of the results, some general remarks are necessary:

- Firstly, all of the studies cited here confirm a **broad individual variance** in the effects they found. This means, the offset of any impacts of ageing and the extent, to which effects occur, differ from person to person. Some of the older subjects in the studies have proven to perform even better than some of the younger subjects.

- Secondly, many studies come to contradicting results, i.e. a result found in one study could not be confirmed or was even contradicted by another study.

- Thirdly, some of the studies cited here suffer from an experimental design, which makes it hard to belief that the tasks used for testing subjects could ever have any relevance for everyday life.

Nevertheless, taking all those restricting factors into account, some general trends can be identified.

The following paragraphs group the results from research with regard to the cognitive function addressed in the studies.

3.1.1 Signal detection

Signal detection can both refer to visual or auditory signals. Most of us are aware of the fact that eye sight declines with age. In more detail, it gets more difficult to follow moving objects, dark adaptation is less and less good, sensitivity of glare increases and recovery time after glare exposure increases.

Hearing tends to decline also in later adulthood; however, difficulties in hearing are less frequent than visual decline. Nineteen percent of people from 45 to 54 years of age experience heavy problems. In general, the ability to hear high-pitched sounds tends to degenerate and the ability to hear speech sound decreases. The difficulty of understanding speech sound gets even greater when the listener finds himself/herself in a noisy environment.

Obviously, this problem may induce serious constraints in auditory communication[4].

3.1.2 Attention

Attention is a global capacity necessary to support cognitive processing. The capacity of attention is limited; therefore information must be prioritised and capacity must be allocated to relevant information based on task-related goals. This overall attentional capacity is considered to decrease with age[5]. However, we can, as illustrated in Figure 3, discriminate between different kinds of attention, namely selective attention, divided attention, sustained attention and automatic vs. effortful information processing. The impact of ageing is different on these different forms of attention[6].

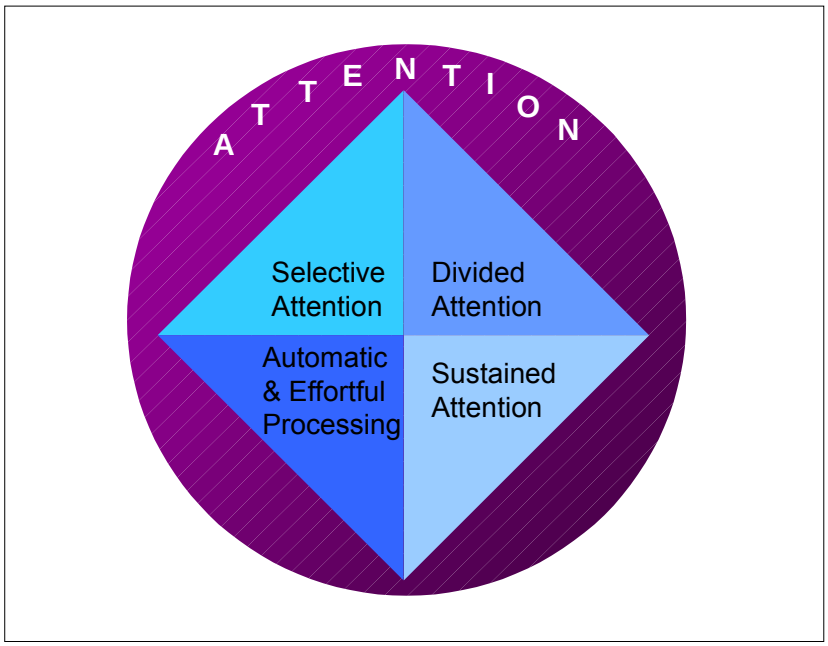

Figure 3: Different types of attention

Selective attention*:* Regarding attention and visual search it was found that older people have more difficulties in discriminating relevant from irrelevant information. This effect increases with increased similarity between target (i.e. the relevant piece of information) and the distracter as noise is introduced. Furthermore, older subjects displayed decreased perceptual flexibility (slower in modifying a perception once they formed it), and have difficulties to identify incomplete figures. However, for many other areas of selective attention (that is, ignoring material that is irrelevant to our current interests or goals) no scientific evidence for age-related differences could be obtained.

[4] Kline & Scialfa (1996)
[5] Plude & Hoyer (1985); Rybash, Roodin & Santrock (1991)
[6] Rybash, Roodin & Santrock *(op. cit.)*; Kline & Scialfa *(op. cit.)*

Divided attention*:* The scientific discussion on divided attention (that is, division of attention between two or more sources of information) is ongoing and controversial. Usually divided attention is measured using dual-task settings (performing two different tasks at once). Both young and old subjects perform worth in the dual-task condition. However, age decrements can be found with increasing complexity of the tasks to be performed. It seems that overall task complexity accounts for age differences rather than the need for divided attention as such.

Sustained attention*:* Performance on sustained attention (that is, to keep up a certain level of attention over a longer period of time) was tested by Thackray and Touchstone (1981) with simulated ATC tasks (radar monitoring). Performance decrement was significantly related to age, with performance declining earlier in the session in the oldest group of subjects. In a follow-up experiment they could show, that a five-minute break after each thirty minutes of monitoring improved the monitoring performance of the older subjects to the level of the youngest subjects[7]. Similar to this study, Vincenzi, Muldoon & Mouloua (1997) examined the performance on monitoring automation failure in a simulated aviation environment. Subjects monitored the system while carrying out a tracking task and a fuel management task. Older adults performed poorer on the monitoring task, they displayed a drop in vigilance rates (indicated by a drop in detection of failures) over the two hours of the experiment.

Automatic vs. effortful information processing*:* As mentioned above, the human information processing system has only a limited attentional capacity to deal with all the incoming information. We can differentiate between two qualitatively different modes of information processing, automatic and effortful. With practice or experience the demand on attentional capacity diminishes as tasks become automatic, placing less demand on information processing. Effortful information processing requires a great deal of attentional capacity. Generally experimental studies do not find any age differences in tasks requiring automatic processing.

These results have major implications for job performance, because skilled workers rely to a high degree on automated behaviour. However, significant age differences can be found for tasks requiring effortful processing, such as the efficient and novel use of control processes, tasks that demand selection and sequencing aspects of attention, or tasks that are especially time-consuming. To summarise, effortful information processing requires attentional capacity, while automatic processing does not. The first declines with age, while the latter does not.

[7] Thackray & Touchstone (1982)

Summary

Regarding signal detection and attention, the following changes occur with ageing:

- vision declines;
- hearing declines for some individuals;
- overall attention deteriorates:
  - selective attention seems to decrease,
  - divided attention seems to remain stable,
  - sustained attention decreases,
  - automated processing of information remains stable,
  - effortful processing of information deteriorates.

3.1.3 Memory

It is generally observed that memory deteriorates as one gets older. However, if we take a scientific view on the issue, the situation is less simple:

- Firstly, human beings do not have one solid and uniform memory; they have different kinds of memory with separated and different functions (see also Figure 4):

  - The first one is the **'sensory store'**. It keeps incoming information for only milliseconds in memory and allows for a first check for the relevance and sense of the incoming information. This process works totally unconsciously.

  - The information which passes this first filter by attracting attention then enters the **'short-term memory'**.

  - This second store keeps information for some minutes. Its function is to process information and pass on material which is considered as relevant to the '**long-term memory'**. The process of storing information in the long-term memory requires that rehearsal takes place (see also Figure 3).

  These types of memory are not equally affected by ageing effects.

- Furthermore, in addition to the age of a person, there are a number of other factors which have a direct impact on memory performance[8].

[8] Rybash, Roodin & Santrock (1991)

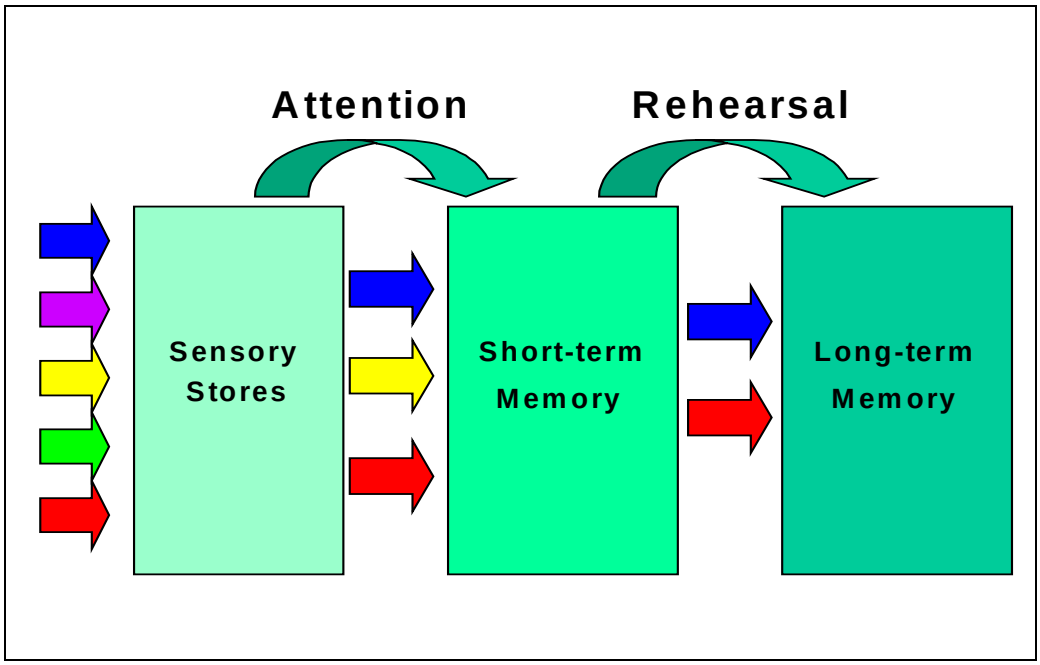

Figure 4: A simplified three-stage model of memory[9]

The sensory store is hardly affected by age.

The capacity of short-term memory is, to a great extent, not affected by age. On task testing short-term memory capacity of fifty years old subjects performed as well as that of twenty years old subjects. Even participants of sixty and seventy years old got almost as good test scores as the younger test groups. However, this result is only valid for healthy older subjects not suffering from any dementia such as Alzheimer.

Nevertheless, the dynamics of short-term memory are, to a great extent, affected by age. There is also indeed the more dynamic aspect of short-term memory which is responsible for processing information, for instance when one is doing a mathematical calculation. This part is referred to as working memory. It selects, coordinates and processes incoming information. Working memory is clearly impaired by ageing. Especially after the age of sixty working memory performance declines substantially. Many research findings point to the fact that it is the speed of working memory which is most impaired[10].

This loss in speed is recognisable in many tasks conducted by the working memory. Two well-examined examples are the speed of searching the memory for a certain peace of information or the processing of spatial information like rotating an upside down letter. Decrements are also observable for tasks which place a high demand on working memory. This is the case if the tasks require manipulation and reorganisation of material in mind. Another task which draws heavy on the resources of working memory is

[9] Adapted from Rybash, Roodin & Santrock (1991)
[10] Salthouse (1994); Craik (1994)

the division of attention between holding some items while dealing with further incoming material. In general, older people get disproportionately worse in task performance the more complex the tasks become and the more they are required to process information in parallel (multitasking).

Age-related differences are more common in the long-term memory. However, the extent to which a difference appears – or whether it appears at all – depends on a number of factors, which are developed below:

- The first factor is the **processing strategy** used for encoding information, i.e. to store it in the long-term memory. We can identify three learning strategies: organisation, semantic elaboration and mental imagery (see also Table 1). The use of these strategies rarely occurs spontaneously but they can easily be taught to subjects. All three strategies have proven to be beneficial for memory recall tasks in all age groups. In some studies the results showed that the use of a strategy would allow older subjects to level out any performance decline in memory. However, other research could not conclude the same results. This fact points us to the next factor influencing memory performance, the nature of the memory test[11].

- The performance in a memory test depends also on the **kind of test** you apply to measure the performance. There are two ways to test memory: free recall and recognition. In a task requiring free recall, the subject is asked to learn the material to be remembered (e.g. a list of animals) and some time later he or she is asked to reproduce as many animals from this list as possible. Under the second condition – recognition - the subjects also learn the same list of animals. However, later they are presented with a different list of animals (both with 'old' animals which were on the initial list and 'new' animals which were not on it). Their task is to identify which of the animals were on the list they initially had to learn.

Table 1: Summary of learning strategies[12]

Process	Description of process	Example
Organisation	The learner actively groups input items together into higher-order units or chunks.	In a long list of words, e.g. *table, bear, spoon, apple, book, raisin, pen, chair, pear*, etc., the learner might group together *raisin*, *apple* and *pear,* and treat them as a single unit *(fruits)*.
Semantic elaboration	The learner associates presented items with long-term memory representations that give access to the meaning of the items.	To remember the word *chair*, the learner might think of *a piece of furniture, you can sit on it, it has four legs, a seat and a back*', etc.

[11] Rybash, Roodin & Santrock (1991)
[12] Adapted from Rybash, Roodin & Santrock (*op. cit.*)

Table 1: Summary of learning strategies *(cont'd)*

Process	Description of process	Example
Imagery	The learner generates a 'picture in the head', 'tape recording in the head' or other mental image.	For remembering the word *flowers*, the learner might think of a picture of a bunch of flowers.

Across all age groups the performance is much higher in recognition tasks. However, in a free recall task there is a clear decline in memory performance the older the people get, i.e. they remember less animals from the list they had learnt. Under conditions of recognition there is almost no age difference in memory performance at all.

- A third factor with a substantial influence on memory performance is the **type of material** that must be remembered. Many laboratory studies conducted in psychology, especially in the early days of this branch of science, used not very meaningful material for their memory tests. At the end of the last century, during his classic experiments on memory H. Ebbinghaus, one of the fathers of this discipline, used in the memory test some material that was not very meaningful to the participants (such as nonsense syllables). However, from more recent research we know, that familiarity of the material to be remembered is very important for memory performance. In a number of studies familiarity and meaningfulness of the items to the participants allowed the older people to perform as well, and even outperform, younger people.

- Finally, a number of **characteristics of the person remembering** influence memory performance; attitudes, interests, health-related factors and intelligence level have a great impact. Also the amount of previously acquired knowledge and skills is relevant. Both factual knowledge and skills are well maintained throughout middle age and into old age.

Summary

Memory can be divided into three separate sections: sensory store, short-term memory (also called working memory) and long-term memory.

- Sensory store is hardly impaired by ageing.
- Working memory suffers from a loss in speed of information processing with ageing.
- Long-term memory performance seems to decline with age. However, the extent of the decline depends on the following four factors: the learning strategy, the nature of the memory test, the material to be remembered and characteristics of the learner.

3.1.4 Spatial reasoning

Spatial visualisation is of high importance for the profession of ATCOs. It is known that the processing of spatial information slows down with increasing age. Well-examined examples of spatial reasoning are perspective-taking ability (i.e. the ability to determine the appearance of a spatial array from a viewpoint other than the one perceived), mental rotation (i.e. determine whether two abstract stimuli viewed from different perspectives are identical), memory for spatial information (e.g. the location of a word on a card), and environmental learning (i.e. abstraction and integration of large-scale spatial information, like learning a new route through town)[13].

On average, an older person's performance on a perspective-taking, mental rotation of objects, spatial memory, or environmental learning task can be expected to be slower and less accurate than a younger person's performance. These effects are more pronounced in a novel setting and when abstract components are involved in the tasks. When the material is concrete instead of abstract and the context is familiar, age differences are reduced or even completely eliminated.

Timothy Salthouse and his colleagues conducted an interesting study with the objective to examine the impact of ageing on spatial reasoning in a group of highly trained subjects. They choose the profession of architects to find out whether extensive experience and practice in spatial visualisation could make up for declines that are observable in less trained older subjects. Their results indicate that older architects display a lower performance on a number of measures for spatial reasoning compared to their younger colleagues. However, they also perform better than untrained persons from other professions do. This finding does not imply a decreased overall professional competence of older architects as there are many, equally relevant tasks of this job which were not tested for in this study[14].

Summary

Spatial reasoning (e.g. perspective taking, mental rotation of objects, spatial memory and environmental learning) gets slower and less accurate with age.

3.1.5 Problem solving / decision-making

The process of problem solving can be described as a set of transformations (e.g. mental operations) that enable the problem solver to reach the goal state from an initial state. In easier words, you encounter a problem when you want something (your goal) and do not immediately know how to go about getting it.

[13] Kirasic & Allen (1985)
[14] Salthouse, Babcock, Skovroneck, Mitchell & Palmon (1990)

To solve a problem we need to create an internal representation of the problem. This representation should encode the critical aspects of the problem, like descriptions of the goal state, the initial state and possible operations to get from one to the other. This internal representation is called problem space. An analogy for problem solving would be to work your way through a maze (see Figure 5). You have dead ends, detours around obstacles, backups to previous points, and a complete path. The more complex your problem gets, the longer it will take to find the correct 'path through the maze'[15].

Figure 5: An analogy of problem solving: Finding your way through a maze

The analysis of ageing impacts on problem solving has to make the difference between problem solving in familiar and in unfamiliar domains.

Problem solving in unfamiliar domains was mainly studied by using games which require logical reasoning. The main findings of these studies are, that older subjects were less efficient in solving the presented problems, although the decline does not generally begin before the sixties or even seventies. Also, older people's performance got disproportionately worse when the complexity of the problems increased. These results could be explained with referring to the problems of working memory (less working memory capacity, slower speed of processing information, etc.) described earlier.

For problem solving in familiar domains the situation is very different. When older subjects are requested to solve a problem in their domain of expertise – for instance, an experienced chess player has to decide on the next move in the game - there are hardly any ageing related declines recognised. On the contrary, as increased age often goes along with increased experience in a certain field, be it a hobby or a profession, older people develop a high degree

[15] Charness (1985)

of expertise in their areas of interest[16]. We will come back to this topic in the next section.

Summary

In unfamiliar domains older people display a decreased efficiency in problem solving, especially if the problems were complex.
In familiar domains there is hardly any impairment of problem solving efficiency and quality due to increased age.

3.1.6 General conclusion

The results presented so far in this section may appear somewhat inconclusive. It is therefore a rather difficult task to provide an overall summary of all the findings. A concept from research on intelligence may be able to provide support for this attempt.

Intelligence is not one single, solid entity. It consists of a number of different kinds of intelligence, e.g. inductive reasoning, spatial orientation, perceptual speed, numeric ability, verbal ability and verbal memory. Besides this fine-grained picture of intelligence there are two broad basic components of intelligence: fluid and crystallised intelligence (see also Figure 6):

- **Crystallised intelligence** includes all skills and knowledge-related aspects of intelligence which are required for solving well-known and familiar problems. It contains factual knowledge about the world and specific areas of expertise as well as procedural knowledge regarding strategies to master a certain aspect of life. We could also call this aspect the ‘pragmatic intelligence’.

- **Fluid intelligence** describes the basic processes underlying information processing and problem solving. It is required for solving new and unfamiliar problems. It could also be called ‘mechanical intelligence’.

Ageing has a different impact on these two components of intelligence. Crystallised intelligence builds up during childhood and early adulthood and stays at the same level or even increases with an extended life span. Fluid intelligence is strongly dependent on healthy brain functions. As we have seen in Section 2, the human brain is subject to a number of degenerative processes that impact on the efficiency of our information processing. Therefore, fluid intelligence declines with increasing age. To sum it up in one sentence, we retain our wisdom and lose our wits[17].

[16] Charness (1985); Glaser (1994)
[17] Horn (1982); Kruse & Lehr (undated)

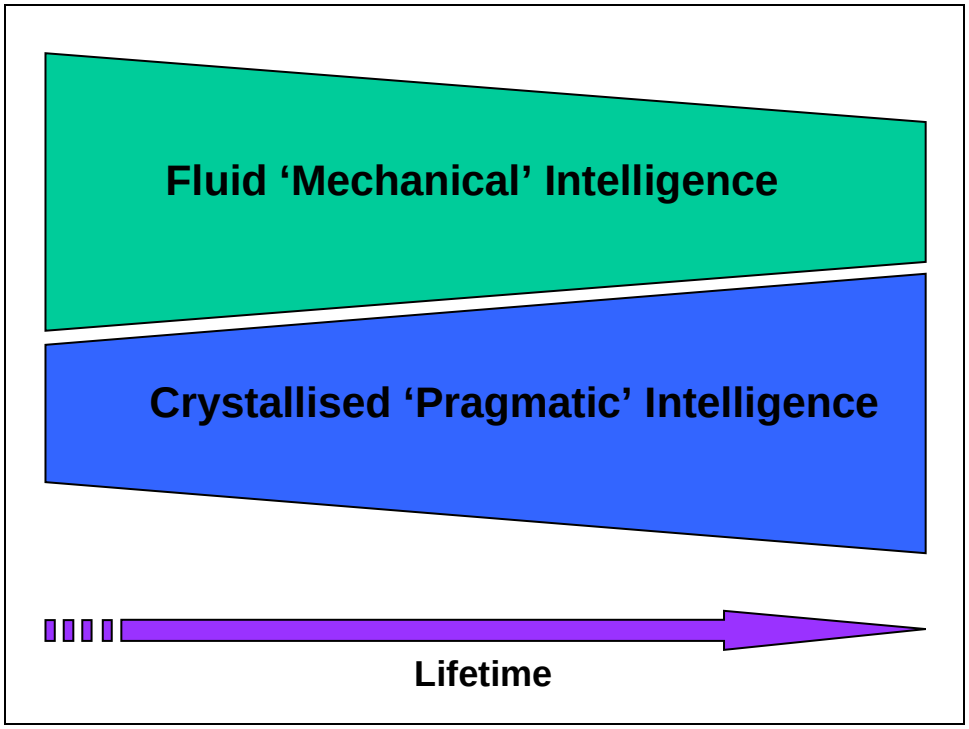

Figure 6: Simplified picture of relative proportions of crystallised and fluid intelligence throughout lifetime

The research efforts in this section have one thing in common: the large individual variability of ageing effects. The onset of decline in mental functions can vary from the early forties to the late seventies. Equally, the extent to which a function is impaired by ageing can be extremely different between two persons of the same age. Mental performance at a certain age is highly dependent on the individual's personal history, it is determined by the sum of specific circumstances and experiences one has encountered throughout life. It is not only the chronological age which impacts on mental performance. There are other factors that might even be of higher importance. These are health, educational level, professional training, lifestyle, motivation and self-perception.

The former German Federal Minister for Family Affairs, Senior Citizens, Women and Youth, Professor Dr. Ursula Lehr, who is also a leading researcher in the area of ageing, condensed these facts when she said: 'There are no ageing norms, only different ageing forms'[18].

3.2 Ageing and Job Performance

The previous section has revealed a substantial impact of increased age on numerous mental functions: signal perception, attention, memory, spatial reasoning, and problem solving. After this rather gloomy picture of ageing, one

[18] Lehr (1997)

would expect a similar discouraging perspective on job performance. However, the situation in the professional world is far more complex and ambiguous than the 'clean' world of scientific laboratories. Although we have scientific proof for decrements in many basic mental processes, we do not necessarily find the same decline in job performance[19].

A general assessment of job performance is almost impossible. Naturally, any classification of job performance depends on the type of profession we are looking at. Also the measures we apply to assess performance has a substantial influence on the result. The two main measures are production records and peer or supervisor ratings[20].

Nevertheless, there are some general trends in the relationship between age and job performance. As illustrated in Figure 7, it can be broken down into components, some of which will decrease with ageing, while some others will increase or remain at the same level.

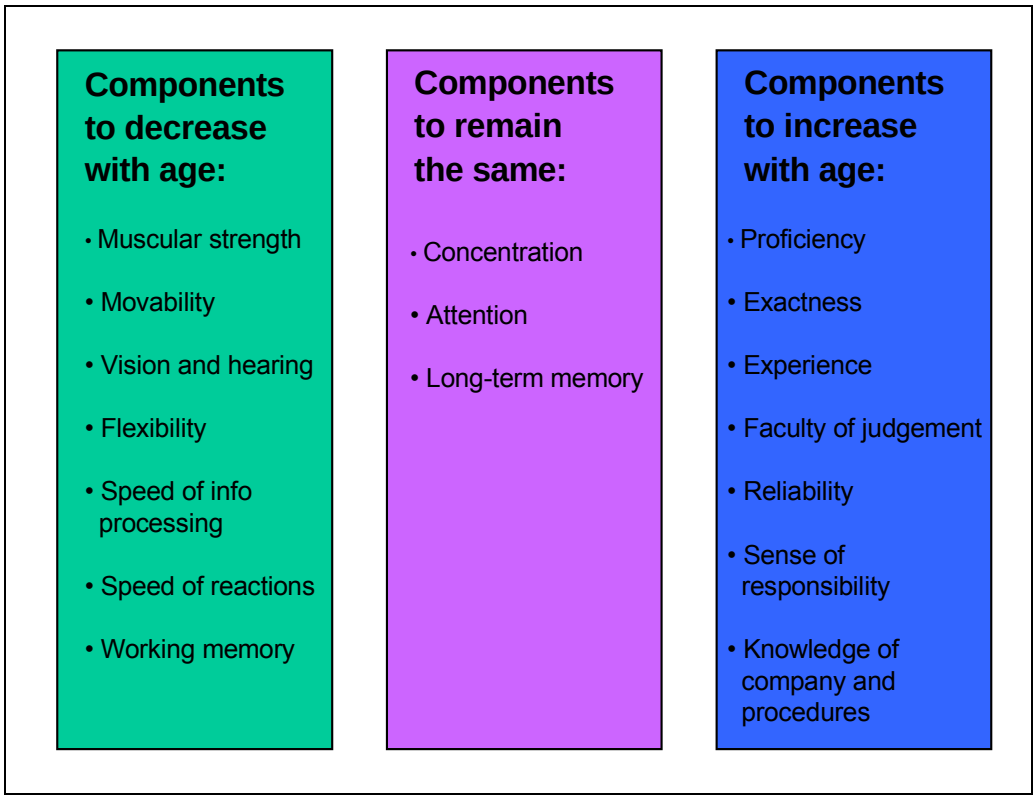

Figure 7: Components of job performance and their variation throughout the professional life

[19] Warr (1994); Salthouse & Maurer (1996)
[20] Davies, Matthews & Wong (1991); Welford (1985); Davies & Sparrow (1985)

A decrease is observable for a number of functional abilities like muscular strength, movability, vision and hearing, flexibility, speed of information processing, speed of reactions and working memory.

An increase is given for a number of abilities like proficiency, exactness, experience, faculty of judgement, reliability and sense of responsibility. Furthermore, older workers have a better knowledge about internal company aspects and production procedures.

Some components of job performance display no change at all, such as concentration, some aspects of attention and most of long-term memory[21].

Interesting features to look at in this context are the occupational age structures. We can assume that over the years of a professional life a selection process happens. Those who feel suited to a certain position or who are regarded as suitable by others have a higher chance to remain in this position. Therefore, the age structures of occupations may, to some extent, be determined by the task requirements and strain which these tasks put on older workers.

Two pronounced developments are recognisable in a broad variety of professions:

- Firstly, older workers have a tendency to move out of jobs with a high physical demand. This trend to transfer to lighter work is particularly marked for unskilled and semi-skilled workers from their forties onwards.

- The second trend is to leave jobs which place a high amount of time pressure on the ageing worker. The pace of work appears to be a major factor in selecting a certain job and it is even more important than the physical demand of the job. Older workers are rarely found in a position with time-stress, either caused by external pacing (e.g. working on a conveyer belt), or by time pressure resulting from a piece-rate payment[22].

The assessment of job performance takes two approaches: production records and performance ratings. Production records are mainly used for manufacturing workers in industry, but also for sales staff or clerical work, while performance ratings are applicable to all kind of jobs, they do not only rely on a physical product as a result of work, but take into account a broad variety of work behaviour.

In most of the studies using production records as a measure for job performance, we find for skilled and semi-skilled workers an inverted U-shaped relationship between age and job performance. Performance increases in the first years on the job, reaches a peak in the late thirties or early forties and shows a slight decline afterwards (see also Figure 8).

[21] Behrend (2000)
[22] Davies, Matthews & Wong (1991); Welford (1985)

However, some studies did not find any decline; frequently workers in their fifties and early sixties perform as well or even better than younger colleagues. Studies of clerical and sales workers discovered equal performance levels between older and younger employees. In a broad survey of the United States Department of Labour, no age differences were found for office workers. The positive relationship between age and job performance found in many studies can be regarded as resulting from the increased years of service of older workers. They seem to benefit from the experience they gain over the years on the job. Experience appears to be a stronger predictor for job performance than age[23].

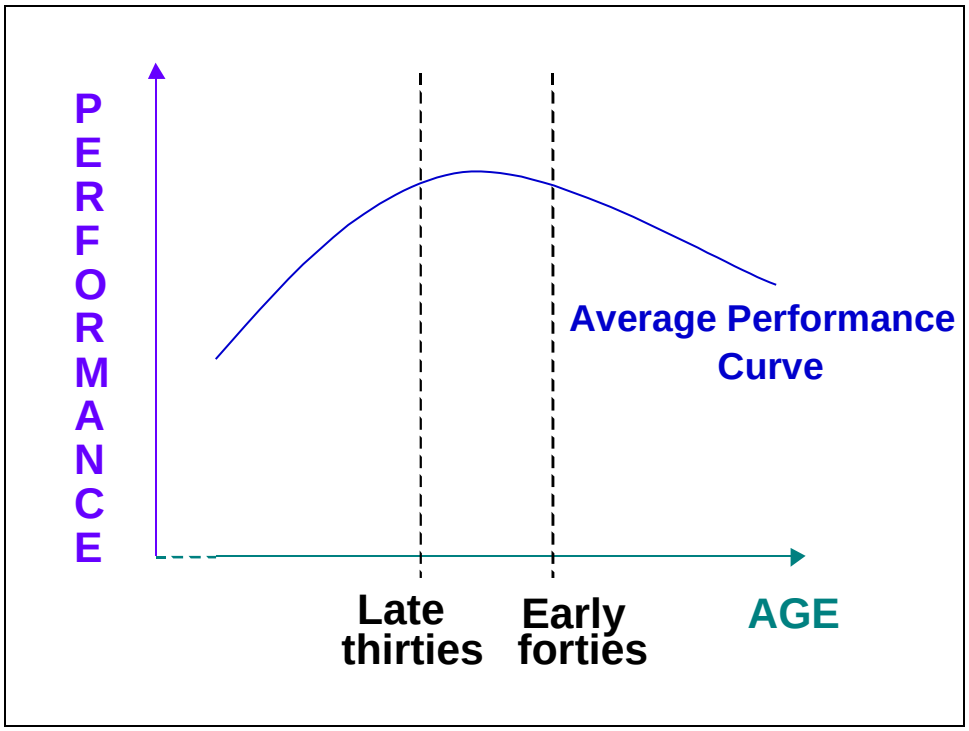

Figure 8: Hypothetical performance curve for various jobs

Performance ratings are an easily applied measure. However, they bear the risk of producing biased results because of negative stereotypes of older workers. In middle and higher management common stereotypes about older workers emphasise their inferior trainability, poorer potential for development, greater resistance to change, and lower productivity. Also younger colleagues and peer workers tend to see their older colleagues in this negative way. Despite the possible negative stereotyping many studies did not find a difference in performance ratings for younger and older employees.

So why do we not find a decline in job performance even though the basic mental processes show such a decline? One possible explanation is the nature of psychological testing. In laboratory experiments subjects are

[23] Davies, Matthews & Wong (1991); Welford (1985); Davies & Sparrow (1985)

required to show maximum performance on an isolated, often complex task and in a condition of time-stress. This is hardly ever the case for work behaviour. Operating at a maximum level is usually only necessary over short periods[24]. Furthermore, success in most jobs depends additionally on motivational factors, interpersonal behaviour and the effectiveness of one's overall work strategy. With increasing experience, a person can develop particularly effective strategies.

Summary

Job performance can be broken down into components, some of which decrease, some of which increase and some stay the same with ageing.

Occupational age structures display the trend that older employees tend to move out of jobs associated with high physical demand and high time stress.

Measures for job performance are production records and performance ratings. Production records show an inverted U-shaped relationship with age for skilled and semi-skilled workers. Peak performance lays mostly between the mid-thirties and the early forties. For sales and office work there is no obvious decline in performance. Performance ratings often suffer from a bias due to negative stereotypes about older workers. Still, many do not conclude a decline of job performance with progressing age.

3.3 Expertise

Job performance is to a high degree determined by experience. It is even a better predictor for job performance than age. To reach an expert level of performance takes about ten years of intensive preparation and practice. It is necessary to learn a great number of specific facts and procedures to master a domain, be it music or chess, painting or researching or being an air traffic controller.

We can find a number of differences between an expert and novice problem solver. Experts view the problem differently, therefore they search the problem space differently. Experts are able to grasp more of the problem configuration at a glance compared to novices. With their extensive knowledge of their domain they have stored patterns of problem situation in their long-term memory. When they have to solve a problem they identify chunks of information in a given situation and try to match them with these stored patterns.

[24] Warr (1994)

Research has identified six major characteristics of expertise:

- Structured, principled knowledge: Elements of knowledge become well integrated, experts store coherent chunks of information in memory. This structure of knowledge allows them to retrieve meaningful patterns in working through problems.

- Proceduralised knowledge: Experts do not only have a broad knowledge base about their domain, they also know how to apply this knowledge and what procedures to use in implementing it. This proceduralised knowledge takes a condition-action form. Experts know what to do and how to do it to solve a problem.

- Skilled memory: Experts use their long-term memory in a way that resembles short-term memory. Therefore, they avoid time-consuming search strategies.

- Automaticity: Another benefit of extensive practice is the automatic accomplishment of certain aspects of a task. As already mentioned in the section on attention, some aspects of attention-demanding tasks can become automated with practice, so that conscious attentional capacity can be allocated to reasoning and decision-making.

- Effective problem representation: Experts often spend an extended time in initial analysis of the problem. They qualitatively assess the nature of the problem and build a mental model (an internal representation) of the problem which allows them to make inferences and add constraints to reduce the problem space.

- Strong self-regulatory skills: Experts develop a critical set of self-regulatory skills, which control their performance. They monitor their problem solving by predicting the difficulty of a problem, allocating time appropriately, noting their errors or failures, and checking possible solutions[25].

It appears that expertise can take a compensatory function for older adults. For example, Salthouse (1984) found in his study that older expert typists compensated for age-related decline in speed and reaction time by looking farther ahead at printed text, thereby giving themselves more time to plan what their next keystroke should be. In work behaviour these aspects of expertise are accompanied by increased interpersonal skills and by a higher competency on complex organisational relationships. All together these factors may give older employees even an advantage compared to their younger colleagues[26].

[25] Glaser (1994)
[26] Salthouse (1996); Charness (1985); Warr (1994)

Summary

Expertise refers to the knowledge and skills of well experienced operators or experts in a certain subject. The six main characteristics of expertise are structured, principled knowledge, proceduralised knowledge, skilled memory, automaticity, effective problem representation and strong self-regulatory skills.

It appears that expertise provides a benefit for ageing employees in a sense that they can use it to compensate for declines in mental abilities.

3.4 Job Performance of Air Traffic Controllers

One of the earliest studies on the relationship between age and job performance of air traffic controllers was conducted by Cobb, Nelson and Mathews (1973) for the US Federal Aviation Administration (FAA) in 1973. They collected performance ratings and other data for over six hundred air traffic controllers in Terminal Area Traffic Control facilities. The ratings were performed by the controller's supervisor, crew chief and one to five peer-level crew team members. 15.5% of the 613 rated controllers were above forty years of age and only fifty controllers (8.2%) had more than twelve years of experience in FAA control work. This study concludes a significant inverse relationship between job rating and both chronological age and tenure in FAA ATC work. However, critique points to the fact that the degree of correspondence between two ratings for the same person was in many cases rather low and also the age of the rater seemed to have influenced the ratings in some cases[27].

According to Becker and Milke (1998) some cognitive functions which are vulnerable to ageing impairments are of critical importance for controllers job performance. Multitasking as the ability to handle simultaneously visual and auditory input, or to return to a task after a break to complete another task are examples for tasks which put a high demand on working memory. They report a lower performance of older controllers on the Air Traffic Scenario Test (ATST), initially developed as a selection test for trainees. Other data they refer to revealed that the older the trainees get when entering the ATC training, the lower their chance is to successfully complete it.

The most recent study on this issue was conducted on behalf of FAA in 1999 by Heil. He used both performance ratings (peer and supervisor ratings) and a Computer-Based Performance Measure (CBPM). The CBPM tested technical skills by presenting realistic air traffic scenarios and two to five multiple choice questions after each scenario. A total of 1,083 air traffic controllers in twelve different en-route Area Control Centres (ACCs) participated in the study. The results revealed that older controllers received lower scores on both measures of job performance. Performance ratings dropped after the age of 49 below

[27] Davies, Matthews & Wong (1991)

the ratings of the youngest age group in this study (31 and younger). Also the results produced by the CBPM displayed an inverted U-shaped relationship between age and job performance. Performance increased until the age range of 38 to 43, decreased slightly in the age group of 44 to 49 and dropped to a low score after 49 years of age.

The above-cited studies appear to prove a decline in ATCO's performance on the job. However, there are some aspects to consider in interpreting these results:

- Firstly, all three studies were conducted in the US. Not only the air traffic there is very different from the European traffic situation (e.g. more homogenous because there are no national – and cultural – borders to overcome in US American airspace), but the training practices are different. Furthermore, the age structure of the US ATCO workforce may differ from the European one.

- The most important reason for careful reading of the cited findings is their limited ecological validity. 'Ecological validity' is an attribute of research which applies to naturally occurring behaviour in the real world (opposed to experimentally evoked 'artificial' behaviour in a laboratory). Studies with high ecological validity take into account natural situations with the entire context of an event, not just a few selected aspects. Applied to our problem of ageing in ATM, this means that the research conducted so far only took into account relatively isolated tasks of the job. Even a test on an air traffic control scenario is still not equal to real controlling on the position.

- With this kind of cognitive testing we do not fulfil the requirements of the work situation for a number of reasons:

  - We are not able to assess the overall work strategies (e.g. prioritisation of tasks, workload management, risk-taking behaviour, etc.).

  - In addition, all the expert knowledge in terms of contextual conditions related to a certain sector is not applicable in such a simulator-based test.

  These constraints may lead to an overestimation of ageing impairments because for older experts it is not possible to apply their expertise in the test situation. However, there is no denial of the fact that a certain decline in cognitive and therefore work-related mental functions is to be accepted.

  - Other factors like social behaviour, especially team behaviour, commitment to the job and the company, attitudes towards the job (e.g. absenteeism), and motivation, are also left aside.

  It is, however, the combination of all these factors which constitutes job performance in the end.

In short, it appears to be too early to draw solid conclusions on the relationship between age of controllers and job performance.

Summary

Some studies conducted in the US point out a negative relationship between age and job performance. Performance seems to decline as controllers get older.

For a number of reasons these results should be treated with care and the transfer of them to the European situation might not be possible without giving more consideration to the differences between the US and European situations

3.5 Ageing, Job Attitudes and Motivation

The picture on ageing and work would not be complete if we neglect the aspects of job attitudes and motivation.

Research in this area provides strong evidence for a slight increase in job satisfaction and job involvement with age[28].

Various explanations for this finding are under discussion, without providing a commonly agreed solution so far. One suggestion is that experience throughout a working life may lead to lower expectations, individuals prospects may become 'grounded down'. Thus, older employees may be more easily satisfied. Another option would be a change in work-related values and needs. With increasing age job security becomes a more important contributor to job satisfaction. Also extrinsic rewards (e.g. financial reward) seem to become more important than intrinsic reward (the satisfaction with work as such). It might also be the case that with increased job tenure employees hold better positions in the company as they have moved on in their career. Despite reaching a higher career stage it may be that some individuals have changed their occupation to one that suits them better and therefore show a higher job satisfaction. Finally, the importance of working life in total may be decreased in older individuals. Their general values and views on life may evolve in a way, that work-related aspects contribute less to their overall life satisfaction.

Thompson and Bailey (2000) examined on behalf of FAA the relationship between age and attitudes in US air traffic controllers. They looked at job satisfaction, quality of work life, organisational commitment, and supervisory fairness.

They also differentiated between several types of ATC services (en-route,

[28] Davies, Matthews & Wong (1991)

flight service stations, levels 1 to 3, or levels 4 or 5 terminal [towers and tracons]). Their overall result suggests a small linear relationship between age and attitudes. Attitudes get slightly more positive as age increases. The scores for job satisfaction and quality of work life increased significantly with age. However, the type of control also has a major impact on the ratings. Ratings were lower for en-route controllers compared to the three other groups. For organisational commitment the result is similar: older controllers have a higher organisational commitment, however, the controllers in en-route and levels 4 or 5 terminal control show less commitment than their colleagues in the other groups. Regarding the perception of supervisor fairness, we also have a similar pattern of results. Older controllers give higher scores on supervisor fairness. Comparing the different types of controllers, levels 4 and 5 controllers report the most positive perception of supervisory fairness.

The importance of motivation and job attitudes for European air traffic controllers will be further discussed in Section 7 of this module.

Summary

Job satisfaction shows a slight increase with age.
A study conducted with US air traffic controllers could confirm this finding for an air traffic control environment.

4. AGE AND SHIFT WORK

Age and shift work is an issue strongly neglected by research. According to Quéinnec; Gadbois & Prêteur-Turbet Delof (1995), out of the thousands of publications from the International Shiftwork Committee only articles explicitly addressed the issue of shift work in relation to age. This is surprising as a huge body of literature is concerned with the consequences of shift work in terms of impacts on social life and health.

Shift work throughout a working career can be subdivided into the following four phases, illustrated in Figure 9:

- In the **Adaptation Phase** during the first five years of shift work the worker has to adapt to changes in sleeping and eating patterns, social and family life and work strain.

- During the following **Sensitisation Phase** a tolerance towards shift work develops, depending on factors like work career, financial safety, satisfaction with shift work and social life.

- After about twenty years of working on a shift schedule the accumulation of environmental hazards and hazards of coping strategies becomes obvious. In this **Accumulation Phase** risk factors, sleep quality and attitudes towards shift work accelerate the biological ageing process and have a strong influence on the health and tolerance of the shift work[29].

- Finally, some workers enter the **Manifestation Phase**, before but also after retirement, which is characterised by an increase of disorders and diseases related to sustained shift work.

Drop-outs (i.e. individuals leaving shift work) can appear at each of the four phases and might display a variation in the ability to cope with shift work.

[29] De Zwart & Meijman (1994)

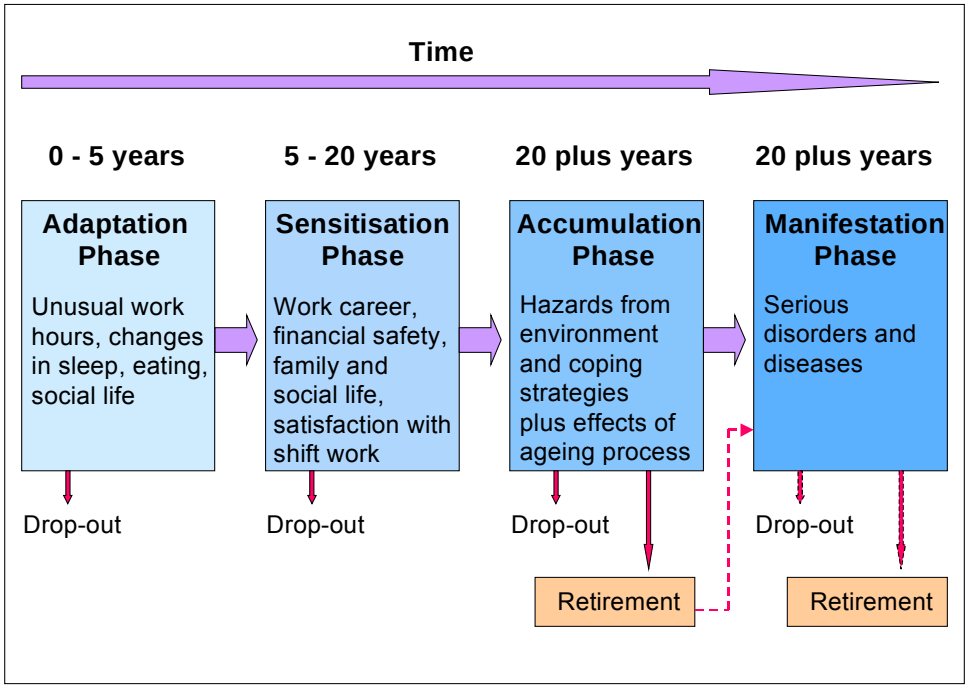

Figure 9: Phases of shift work throughout a working career[30]

Publications on shift work stress the fact that atypical work schedules range top of the list of unhealthy work conditions. The so-called 'shift worker's syndrome' can appear at any age. It is characterised by a number of typical health problems. The main symptoms include reduced and altered sleep, digestive disorders, cardiovascular problems, endocrine disorders, and mental imbalance associated with general fatigue[31].

The same trend as reported for heavy physical work and for work under time pressure can also be observed for shift work. Older workers take the opportunity to leave these highly demanding working conditions whenever possible. They quit shift work, especially night shifts and change to day-time work. In occupations where there is a permanent demand for night shifts older workers appear to work less night shifts compared to their younger colleagues. It seems to be almost a privilege of seniority to reduce the number of night shifts[31].

If we take a look at the negative consequences of shift work, it appears that they are compounded for older workers. The two main groups of complaints relate to sleep disturbances on the one hand and health problems on the other hand.

Reduced sleep length and quality of sleep are frequently reported results. Older shift workers seem to have more trouble with night-time or early morning

[30] Adapted from De Zwart & Meijman (1994)
[31] Quéinnec, Gadbois & Prêteur-Turbet Delof (1995)

awakenings compared to their younger colleagues who suffer more from difficulties falling asleep[32]. Although sleep patterns change with age, even for workers on a 'normal' work schedule, these effects are more pronounced for people on a shift schedule. The number of hours of sleep for night workers seem to decrease, and also the patterns of sleep changes[33]. A consequence of disrupted sleep is a decrease in vigilance during wake periods, also during work hours. This is a finding many ATCOs may be able to relate to, as most – if not all – of them know about the problem of keeping a sufficient level of vigilance during the early morning hours of night shifts. Research on ATC incidents and accidents reveals a substantial contribution of fatigue to incidents, although we have no evidence that the night shift as such is a more error-prone period[34].

When we look at the health of older shift workers we have to consider that we are talking about a sample of people already selected according to health criteria. Many individuals on a shift schedule quit work (i.e. change to a day-time job or go for early retirement) because they suffer from health impairments. The ones who stay are those who cope best with atypical working hours. However, this relatively healthy group remaining suffers from a cluster of diseases, marked by a general deterioration in health throughout years of shift work. Older shift workers report more gastrointestinal and skeletal diseases, more respiratory infections and disturbance of appetite and indigestion, and also the risk of ischaemic-related heart diseases seems to increase[32]. A very well conducted study from a methodological point of view investigated shift workers in the newspaper industry. They concluded an increased risk of early mortality for shift workers, possibly because of the decreased resistance of the organism to severe work stress[33].

Zużewicz & Kwarecki (2000) conducted a study on the effect of shift work on the heart rate, fatigue and sleep of ATCOs. They studied 97 controllers in an approach control facility. Their results show changes in the circadian rhythm of heart rate for all examined controllers, both on day and night shift. The authors also found a need for longer recovery time for older controllers after a night shift. They increased their nap times after the night duty more than their younger colleagues[35]. However, a complete assessment of the impact of shift work on controllers' health cannot be made from these results.

[32] De Zwart & Meijman (1994)
[33] Quéinnec, Gadbois & Prêteur-Turbet Delof (1995)
[34] Luna (1997); Della Rocco & Cruz (1996); Della Rocco (1999)
[35] Zużewicz & Kwarecki (2000)

Summary

Shift work has a negative impact on health: it affects the length and quality of sleep, induces digestive disorders, cardiovascular problems and endocrine disorders, and can cause mental imbalance often associated with general fatigue (the 'shift worker's syndrome').

The negative impacts of shift work on health and well-being are compounded by ageing.

5. AGE AND CAREER DEVELOPMENT

For most controllers their working time as an operational controller will be shorter than their entire working time until they retire. Sooner or later most controllers find themselves faced with changes in their interests or in job performance. When becoming aware of these changes, be they due to the fact that working night shifts becomes more demanding or that the constantly increasing traffic load gets more and more difficult to cope with, many controllers consider career alternatives to operational work[36].

Between the age of 40 and 45 years a need for medium- to long-term alternatives to the operational job may become an issue. There are some alternatives available, which remain highly related to the operational work (see also Figure 10):

- **Supervisory tasks**, and the area of **selection and training of ATCOs**.

  Most controllers are involved already from a quite early stage in their career in On-the-Job Training (OJT) of new controllers. Some controllers develop a deeper interest in training issues and move onto simulator training or institutional training. The selection process of *ab initio* controllers requires input from the operational side in almost all European countries. Supervisor positions are limited in number and therefore provide only for a few controllers a perspective way forward.

- An additional broad field of activities is the **development of new technical systems**.

  The involvement of experienced operational people in the development, pre-operational testing and implementation of advanced technical systems can be regarded as a crucial feature for their success. It is not only the pure operational knowledge of these people, which will help the technical engineers side to figure out what will work in the (Operations) OPS room and what will not. It is also the credibility amongst their colleagues, which makes the advice of elderly and highly experienced controllers so valuable for system development.

[36] EATMP (2000b)

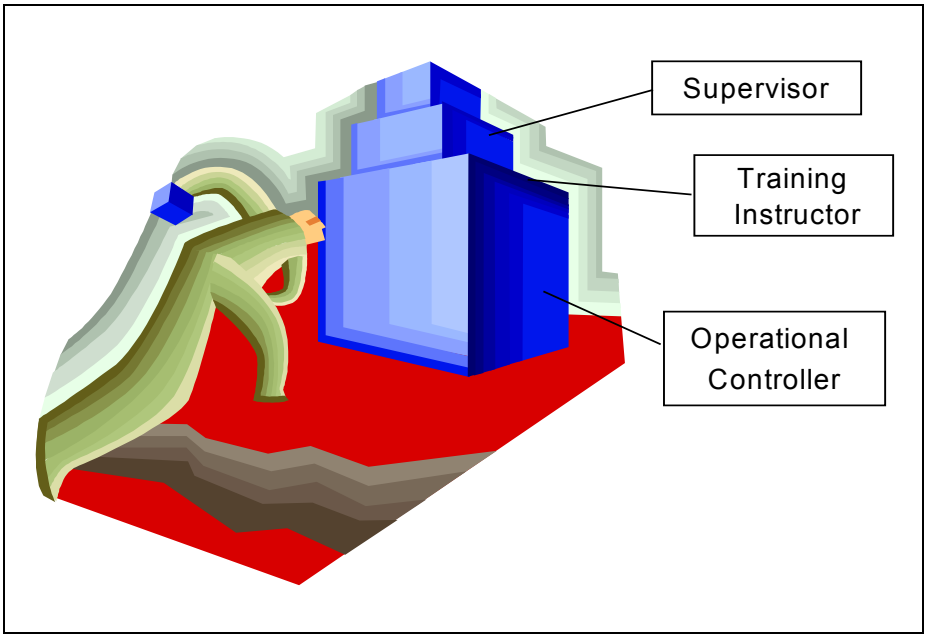

Figure 10: Possible career steps for an ATCO

Despite all the above-mentioned existing alternatives, what is missing in many Air Traffic Control Centres (ATCCs) is a systematic, and for operational personnel, transparent and reliable approach towards personal and career development.

The above-listed options relate to the situation where a controller wants to move away from an operational position or limit his or her time on this position. However, what happens to those controllers who do not want or do not have the opportunity to make this change, but feel that they are reaching their limits in their current positions? From anecdotal reports we know that in many ATCCs this problem is solved in the OPS room. There are many ways of dealing with it. The first and maybe most obvious one is that supervisors or watch managers take the age (and associated performance levels) of their staff into account when manning the positions. They can be expected to be well aware of the performance levels of their staff and allocate them appropriately. Often older controllers are not put on the 'hot seats' any more, so that they do not have to work stressful and highly demanding sectors during peak traffic hours.

It is frequently regarded as a good combination to have a younger controller on the radar (executive) position and an older controller with lots of experience as a team partner on the planning (coordinator) position. Also the distribution of night shifts appears to take into account the age of controllers, at least in some centres. Older controllers tend to work less night shifts, a fact welcomed by many younger controllers, as they are in a period of life (founding a family, building a house, etc.) where they have higher requirement for the financial benefit of night work.

The flexibility of the operational environment in handling the problems of older controllers faces serious constraints when it comes to staff shortage. On average the extent of ATCO shortage in Europe ranges between ten to fifteen percent. This lack of people makes it often impossible to take the individual's needs fully into account. At certain times it might be unavoidable to allocate a less fit person to a busy sector. It might be equally unavoidable to adjust night shift to the health requirements of older controllers, leading to accumulated fatigue and health problems – which in turn will increase the absence times and worsen the shortage problem.

There is no easy solution for this problem. Many factors contribute to the situation and have to be taken into account. Within the EATMP Human Resources Programme, the Manpower Sub-Programme (MSP) Team of the EUROCONTROL DAS/HUM Division is currently developing tools for improving medium- and long-term manpower planning and career development[37]. These efforts will be a contribution to coming closer to a solution.

[37] See EATMP (2000b, 2001 and 2003e)

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6. AGE AND AUTOMATION

Modern technology is an integral part of our lives. At work, in our homes, in the public, the support of technological aids can be found everywhere. Modern telecommunication devices, personal computers, automated features in transport systems or in banking are only a few examples. The more sophisticated technology gets, the more functions are available on the devices and the higher their complexity[38]. For younger people this is a natural component of day-to-day life. But how do older people cope with it?

Unfortunately, the topic of ageing and new technologies at work has not attracted much research so far. The available body of literature focuses on a number of issues not immediately relevant for older employees. Four research trends can be identified, all of them not directly linked to work.

The first branch of studies looks at very old people with a higher likelihood of suffering from disabilities and how they could be supported by modern technology. Questions of user friendliness, acceptability and design of technological aids are discussed under this heading. Especially modern telecommunication devices are of interest here, for instance for calling for help in a medical emergency[39].

A broader view is taken by research focusing on design for the elderly in more general terms. How should a display look, if somebody with decreased eye sight is supposed to use it with ease? How should the buttons look and feel, if the potential user suffers from decreases in the tactile sense? The specific needs of older people have to be addressed also on a functional level. How many modes can a device have before it gets confusing or over-complicated? If some of the younger readers of this document felt spontaneously addressed by these questions, even if they are not yet forty, this is not surprising. One of the rules of good design for old age is that it is helpful for all age groups. People of all ages would benefit from it, the older user possibly a bit more than the younger.

Another area of research is computer usage of older people. Many studies and public research projects are concerned with this issue. The driving force behind this is the overwhelming importance of computer in today's life. The objective of many projects in this area is to teach computer skills to older adults which are not yet computer-literate. Individuals who did not have the chance to gain experience with computers often have to overcome a barrier to approach a PC for the first time.

Teaching computer skills to older adults is a challenge, because they may be 'pupils' with higher demands than their younger counterparts. Both the content and the way it is delivered need to be adapted to the target group. To adults the content must make sense, they are not willing to learn theoretical material

[38] Ruediger, Espey, Neuf & Paus (1994)
[39] Rabbitt & Carmichael (1994)

if they cannot see the practical use of it. Also the didactical style needs to suit adults. They should be treated on an equal level and not like immature children. The pace of learning can be expected to be slower for older adults. They learn best if they can extensively practice the new skill and if they can learn at their own pace without pressure. It also turns out to be of benefit if the teacher is the same age as the trainees.

A special difficulty in computer usage of older people is the use of the mouse as an input device[40]. Apparently it is more difficult for them to use the mouse due to decreases in motor control as part of normal ageing. Especially fine-grained sub-movements and more complex tasks like double-clicking present a problem for the older user. A simple design solution would be to avoid double-clicking functions.

The fourth area of research addresses the use of technology by older people in day-to-day life. This issue is of high public interest, as older individuals may suffer from serious constraints in the participation of public life if they are not able to handle certain machines. A German research group examined the usability of various electronic devices, amongst which were ticket dispensers for public transport in a big German city[41]. They observed about 1,400 users of the ticket dispensers and found out that sixty percent of elderly subjects had problems in understanding the information on the price system. 25% of the elderly gave up buying a ticket after several unsuccessful trials. This finding reveals the severity of the problem. This group of older people is faced with a limitation in their mobility because they are not able to handle the technology associated with it. In another study the same authors also revealed that older people have problems with getting used to multi-mode functions, for instance on remote controls.

Research addressing the issue of older employees and technological change is also primarily focused on the introduction of computer systems. They are the most widespread form of technology, affecting most professions in all branches of economy. Research conducted in France revealed that it is not necessarily the age of a person which causes a negative attitude towards computers, it is rather the amount of experience one has with computers[42]. When people get the chance to gain experience with PCs their attitudes become more positive proportional to the amount of experience.

A number of characteristics of new technology provide a challenge for the ageing worker. Many human factors issues associated with the introduction of new technology are to be addressed for all age groups, such as trust in automation, skill set changes, new error forms, changes in teamwork, situation awareness and workload. It can be expected that these problems will be even more pronounced for ageing employees.

A first critical aspect of computerisation is the shift of incoming information to the visual channel. Information displayed on the screen replaces more and

[40] Smith, Sharit & Czaja (1999)
[41] Ruediger, Espey, Neuf & Paus (1994)
[42] Marquie & Baracat (1995)

more other sources of data, e.g. auditory information via telephone. The introduction of datalink into the aviation world is such an example, where Radiotelephony (R/T) communication gets replaced by visual information. For employees of any age this trend bears the risk of causing visual overload. For air traffic controllers this loss of other sensual modalities for information intake may also decrease the possibility of multitasking. No research is available to confirm this concept; however, from a theoretical point of view, it appears to be a reasonable assumption that one cannot split visual attention over several sources at the same time. A controller being occupied with solving a conflict in one corner of his or her screen might not see a flashing label in another corner. However, if the information in this flashing label would be transferred to him or her via R/T, he or she would still be able to take this information in. Wickens' (1992) Model of attention and working memory would be in favour of this assumption (see Figure 11).

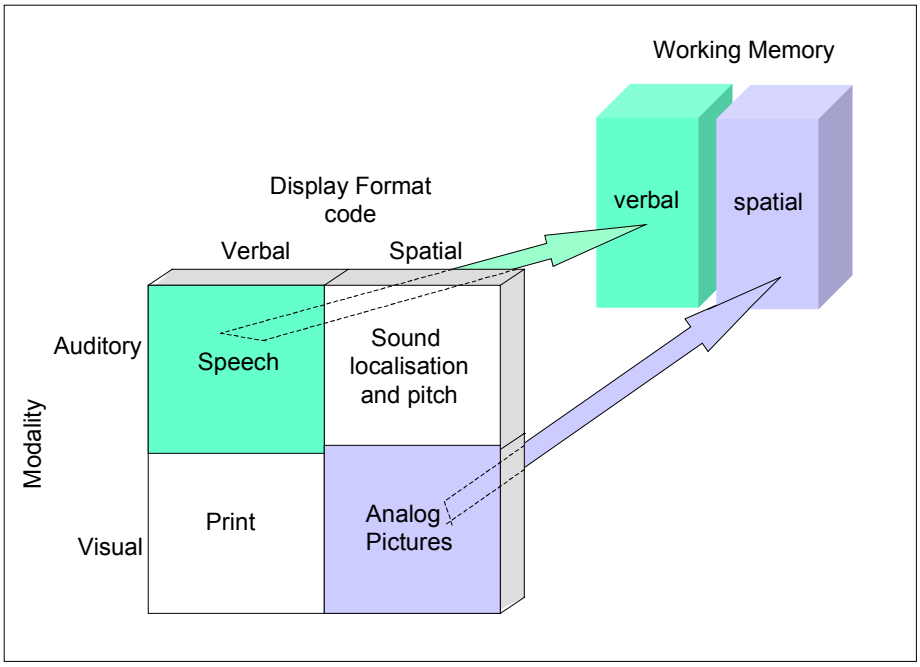

Figure 11: Optimum relationship between information code, sensory modality and working memory[43]

According to Wickens, information processing is facilitated if the information code (verbal or spatial) corresponds to the sensory modality (visual or auditory) and therefore addresses different functional areas of working memory (verbal or spatial processing). Information using the same sensory input channel possibly causes interference.

Regarding trust in automation little is known about the attitude of older employees. They generally have a higher reluctance to change and therefore

[43] Wickens (1992)

might be also less prepared to trust a new system. At least for some of them it seems to cause discomfort to have to rely on the computerised system. Many old operators are very familiar with the system they used to work with, they know all possible bugs, all kinds of shortcomings or unexpected system behaviours. The older operators have collected years and years of experience and know how to interpret an unusual system state. Also the appropriate strategies to deal with a deviation or failure of the system is known. A new system may appear frightening to them because they have to start this process of gathering experience from scratch again. This situation is compounded by the fact that modern systems require a huge amount of background information to be able to diagnose a system failure or deviation. The acquisition of this theoretical information is more demanding of older people and might take longer for them.

Another challenge provided by new technology is the possible increase of mental workload associated with it. Already the training for new equipment places a high mental demand on the trainee, even more if he or she is over forty years of age. The time immediately after the training, when new skills and knowledge are to be applied in the normal work setting, is critical for all employees. When they are faced with the new equipment on their own shortfalls in training and deviations from theoretical concepts become apparent. This is the time when mistakes occur and the chance of getting discouraged is very high[44]. During this period a substantial amount of attention has to be allocated to handling the equipment, therefore less capacity is available for doing the tasks of the job. In air traffic control this would mean that less capacity is available to effectively deal with the traffic.

For many new automation devices in ATC the impact on controllers mental workload is still unclear. Features of display design (e.g. font size, contrast, amount of information displayed, etc.) are equally important as the organisation of tasks and task sharing between human and machine. We can assume however, that workload problems associated with new technology will be more pronounced for the older controller. Here also the rule applies, that good design will support all controllers, however, the older ones will benefit even more.

A general concern for older employees with regard to technological change is the danger of becoming outdated. Expertise gathered over years might become obsolete because of new developments. Not only where professional knowledge is concerned, but also work procedures may change drastically if new equipment is introduced. As discussed in the section on expertise, some aspects of expertise appear to be useful to older employees to compensate for ageing declines (remember the older typewriters). For exactly this reason technological change provides a challenge for ageing individuals. Due to changed working procedures they might no longer be able to use compensating strategies. For example those aspects of tasks which were mentally automated in the old system (e.g. marking a flight progress strip) may

[44] Marquie & Baracat (1995)

require attentional capacity in the new system (e.g. making an input with the mouse) because they are unfamiliar to the operator. A possibly dangerous aspect of this process is the falling back on old habits when operating a new system. Especially under high workload it can happen that an old procedure is retrieved from memory and executed because attention is absorbed by other tasks. In ATC such a mechanism potentially causes dangerous situations.

There could also be positive aspects to this. System design can take into account the expertise of system operators. Involving older operators early in the design process could benefit the result of the design process. It could facilitate the transition of expert knowledge from an old to a new system, helping operators of all age groups to handle the new system.

Summary

The issue of age of employees and new technology has attracted little research so far. It appears that older employees have a higher reluctance to use computers. However, if they get a chance to gain experience the negative attitude becomes more positive.

The human factors problems associated with the introduction of new equipment can be expected to be even more pronounced for older users.

Interface issues and workload impacts should be carefully considered.

Technological change bears the danger of out-dating expertise. The design of new systems should facilitate the transfer of expertise form the old to the new system.

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7. HOW DO CONTROLLERS SEE THE ISSUE?

The fact that we do not know enough about the consequences of ageing for ATCOs can be regarded as the major conclusion from the literature review. Although there are a few studies available dealing with the issue, many questions remain unanswered. However, defining requirements for further research always bears the danger of following the interests and scientific 'hobby horses' of the researcher rather than operational requirements. With the intention to avoid such a biased approach we decided to conduct an interview survey to find out about the perspective of operational staff on the topic. How do controllers see the issue? Is it an issue for them at all? Do they recognise any changes in their work behaviour due to growing older? What is the role of experience in a controller's job life cycle? What is their experience with transitions to new technical systems?

7.1 Participants

Six European Area Control Centres (ACCs) in five EUROCONTROL Member States participated in the study. They volunteered to take part after having been addressed by the corresponding national member of the HRT Human Factors Sub-Group (HFSG), now known as the Human Factors Focus Group (HFFG). The five States were Hungary, Portugal, Sweden, The Netherlands and the United Kingdom. To adhere to data protection the exact location of the centres will not be reported.

The distribution of the centres over the geographical regions in Europe was chosen to balance the influence of cultural differences in dealing with the topic. Unfortunately, it was not possible to get access to an Area Control Centre (ACC) in the South-East of Europe.

The selection criteria for the participating controllers was their age: only controllers above forty years were asked to be involved. All of them participated on a voluntary basis. The minimum number of people per centre was twelve. However, one set of interview data from a Swedish centre was lost because of technical data recording problems. The resulting number of interviews, i.e. data sets, was as follows: eleven from Sweden, twelve from Hungary, twelve from Portugal, seventeen from The Netherlands, and 24 from the UK. The total number of interview data sets available is 76 (see Figure 12).

The average age of participating controllers was 49 years, range 39 to 64 years. Two of the subjects were in fact 'only' 39 years of age. However, as they participated in the two centres where the minimum number of twelve was over subscribed, they were not rejected. Four of the interviewed controllers were female (one in Portugal, one in The Netherlands and two in the UK). The average years of experience in the job was 26, ranging from 13 to 38 years.

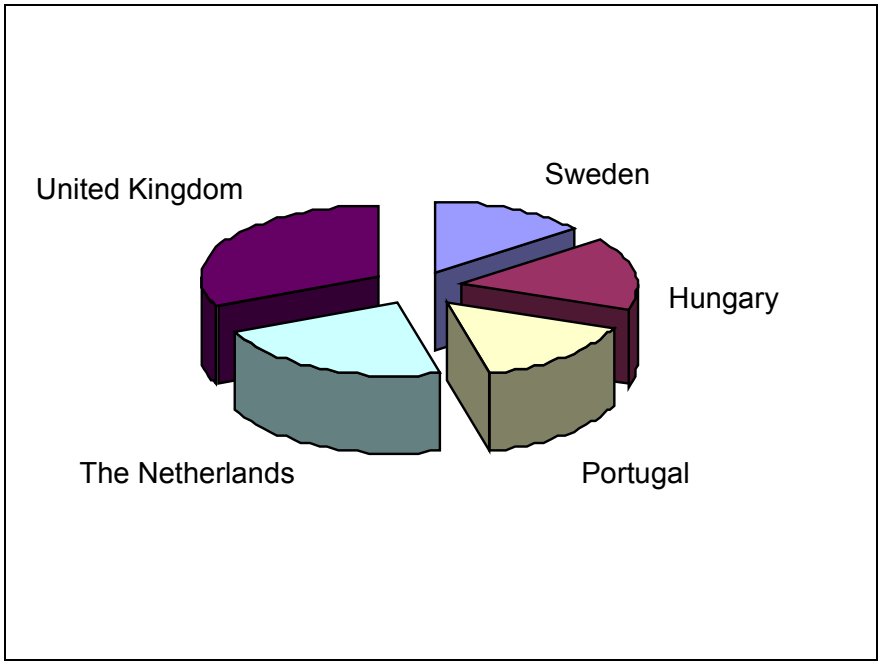

Figure 12: Distribution of participants over countries

7.2 Interview Setting

The interviews were conducted on a one to one basis, i.e. only one controller was interviewed at a time. In three of the centres a separate room was provided for the interviews; in two centres they were carried out in a quiet corner of the ops room.

A set of slides was prepared to give an introduction to the project. However, in only one centre the necessary facilities were available. In the other four centres the introduction was only given verbally.

The duration of the interviews ranged from 25 to 60 minutes, depending on the time available by the controllers. In situations where the controllers had to do the interview in their break time the number of questions was cut down to the minimum to minimise the additional effort placed on the participants.

Additional variability evolved through the fact, that most of the interviewees were not English native speakers. To increase understanding, the questions were reformulated if the interviewee had difficulties in understanding them.

The answers were recorded in handwritten format. A first attempt to record the data on tape failed because the quality of the recording was too low. Subsequently, the paper and pencil version proved to be the best option.

7.3 Results

The reader may be reminded that the findings presented are based on qualitative interviews. Therefore, the nature of data is subjective. It reflects the personal experiences and opinions of the interviewed controllers. The results cannot be regarded as scientifically proven.

7.3.1 What are the issues concerning controllers with regard to getting older in the job?

Asked about their general concerns related to getting older in the job a broad variety of issues was raised by the 76 interviewed controllers. Most frequently mentioned was the aspect of dealing with change, i.e. the adaptation to it and coping with it. 28 statements of the interviewees related to this issue. It seems to be rather the rate of change that has the potential to create a problem, as the amount of information to be maintained constantly increases. Frequent changes make it difficult to remember the last alteration and presents a danger of confusing memory banks when trying to retrieve the latest information.

In all of the five centres the transition to a new system which had recently happened or was about to happen in the near future caused unease. For many controllers it was difficult to see the benefit of it. Furthermore, for those who were not yet familiar with computers, the transition presented a challenge.

A second area of concern addresses the topic of job demand. Fourteen controllers stated that night shifts get more demanding the older they get, and nine mentioned increased workload and complexity. Closely linked are the concerns related to performance changes due to ageing (stated by thirteen interviewees). It seems to become more difficult with increased age to keep up with the increasing level of traffic and subsequently caused high time pressure constraints. However, six controllers stressed the individual variability of ageing impairments.

Possibly as a consequence of increased demand, eight controllers pointed out health issues as a concern. One explicitly mentioned fatigue as a problem.

Another area is the difference between generations of controllers. In centres with an age gap because of recruitment stopping for several years, these differences or even conflicts are well noticed. Primarily the diversity in working styles could possibly create conflicts between older and younger ATCOs (five statements). It is also difficult for the older colleagues in that they can often spend less time on position (five statements) and therefore suffer from a lack of practice, for instance if they have to spend too much time on their supervisor function.

Older controllers tend to be less involved in the various additional projects ongoing in their centre (four interviewees), and therefore less likely to make an impact, for instance on the design of a new system.

Three ATCOs talked about the problem of career alternatives in case one cannot cope with the operational work on position any longer. These cases are highly concerning for controllers, as they can imply a loss of their licence. In very busy centres some controllers give back their validation for certain sectors voluntarily, as they are aware of their own limits.

The increased demand for training, e.g. for airspace restructuring; for changes in procedures; or equipment, was mentioned as a negative aspect by three controllers.

Single comments related to bad contacts to management, a decreased quality of training (for the new controllers), old equipment, personality aspects, lack of self-awareness, the salary and finally English language skills.

Most of the issues briefly addressed in the first question have been discussed in more detail in the subsequent interview and will be presented in the next sections.

7.3.2 What is the perceived impact of age and experience on job performance?

All of the effects described below have to be seen in the light of the constantly increasing traffic load over the last decades. Since the controllers interviewed in this study entered their career in air traffic control they have had to manage an ever increasing traffic load. As growing older in the job and dealing with constantly rising traffic demands are so interwoven, it is not possible to clearly separate those effects caused by age and those caused by increased job demand; at least not by using an interview approach. Therefore, the results presented here should be treated with care and not be generalised.

7.3.2.1 Impact of age

Most controllers (twenty of them) stated that there is only a small or even no impact at all of age on job performance. However, almost as many pointed out a negative impact (seventeen ATCOs). A positive impact was reported only by five interviewees and five emphasised the individual variability of performance. Two controllers described a recognisable change in performance with increased age. However, it is not possible to determine whether these changes are for the better or worse. The positive effects of age will be elaborated on under the section ‘Impact of experience’.

Slowing down in information processing speed: The most pronounced impact seems to be a general slowing down in the speed of working and information processing (sixty statements). This slowing down seems to concern all kinds of tasks, and apparently it affects basic tasks less, even though it is more recognisable in complex tasks (two statements). There is a broad individual variance in the onset of slowing down, and it appears to start between the age of 40 to 45. After the age of 50-52 it becomes more evident. This process is particularly accentuated as the controllers have to keep up with the increasing traffic at the same time – ‘time is your enemy’ as one of the controllers put it.

There are a number of influencing factors in addition to the age of a controller that impact on speed:

- Firstly, the pressure of high workload aggravates the slowing down, e.g. taking decisions takes longer (three comments). Sufficient experience helps the older controllers to get over high traffic levels but this causes more fatigue for the controller.

- Secondly, it is the position one is working at which indicates one is working slower (four statements). The radar position is much more affected by the consequences of ageing than the planner or coordinator position is. In more general terms, ageing impacts are more recognisable in tactical than in strategic sectors.

- Thirdly, the time actually spent on the radar position is a major influence on working speed. As soon as a controller stops working fulltime on a radar working position, he or she starts loosing skills and speed. Two ATCOs stated they found it more difficult to come back after holidays. Special situations (e.g. holding in bad weather) which do not occur very often are more critical. They take longer to react to when compared to a basic standard situation.

- Finally, it depends on the personal working style as to how fast one notices slowing down.

Job demand: Fifteen controllers pointed out that they find the job more demanding, four of the interviewees felt they are dealing with their limits in high traffic, three stated to avoid peak traffic, because they do not feel comfortable any more working with high traffic numbers. Seven of the interviewed ATCOs believe they can handle less capacity compared to when they were younger. Working high traffic loads is more exhausting, especially after 50 to 55 years. Six of the interviewed controllers find it harder to cope with stress, and mentioned health impairments such as back problems, high blood pressure, eye sight deterioration, etc. Proper ergonomic adjustment of workstations becomes more important as the ageing body is less tolerant for example for twisted seating positions. Seven ATCOs talked about recovery time after duty. They need longer recovery times and feel more tired now compared to when they were younger. Night shifts in particular are increasingly demanding.

Learning: Learning something new becomes more difficult with age. Twelve controllers referred to the fact that it is more difficult to pick up new concepts and especially theoretical knowledge; for instance, technical background knowledge about a new system is harder to acquire. Consequently, older controllers are more selective in which new information to learn.

Multitasking and complexity: A broad area where increased age has an influence on performance is multitasking and dealing with complexity. Both seem to get more difficult with age. The controllers have the impression of having less thinking time available, and get confused more easily, and

multitasking gets more demanding (ten statements). R/T communication can get very heavy in high traffic situations. In addition, other areas of mental activities like memory (five comments) and sustained attention (four statements) are impaired by ageing. Some find they are less flexible in their work (five controllers). For some it becomes more difficult to keep the overview of the situation (three comments), and three ATCOs feel their mental traffic picture is more limited.

Self-perception: With increased age not only the way the job is done changes, but at the same time self-perception of people (three statements). The performance decline is likely to have a negative impact on how controllers perceive themselves. Some mention that their self-confidence is lowered (three comments); as they are aware of the decrease in performance they have to overcome a kind of mental barrier. The step to take for them is to see their limits and accept them and deal with them appropriately. Some mentioned that they lose their temper quicker. However, it can also cause problems if one is not aware of his or her limits. For colleagues who have to deal with older controllers unaware of their performance decline, this can be a difficult situation.

7.3.2.2 Impact of experience

Despite all the above-mentioned negative changes due to age there is also a positive side to ageing, that is experience. Experience is a benefit leading to increases in performance in various areas. 54 of the interviewees were of the opinion that experience is helpful in doing the job and compensates (partly) for negative ageing effects.

Long-term memory: Naturally, with more experience people have a broader memory bank for traffic situations and solutions. 42 interviewees referred to having better situational knowledge, and 28 talked about having better knowledge of conflicts and resolutions. Controllers build up a library of solutions, from which they can retrieve the best and safest solution for the current situation. They know, which one worked out well in the past. Standard as well as non-standard situations are resolved quicker, in an almost automatic way (looking at a situation and knowing instantly how to solve it). Many aspects of the behaviour get automated (nineteen comments), active problem solving or thinking is less required. Doing the job is more routine, for instance in strip reading: knowing instantly what it means saves time. With more experience controllers have also a broader context knowledge (thirteen statements), that is they are more aware of the relevance of all kinds of information which may have an influence on their work, for instance performance characteristics of different aircraft types, runway configuration of a major airport close by.

Anticipation: Experienced controllers are better in anticipating, know how rapidly things can change, and know where and how problems are caused (36 statements). They know what to expect from a traffic situation so that there are hardly any unexpected situations for them. They spot potential problems early on and are able to pick out quicker which aircraft will be a problem. With

more experience they tend to look at a wider picture and take a broader perspective on the situation. Five controllers believe the older colleagues are better in planning the traffic.

Resource management: In the course of time controllers get better in adjusting their workload (five comments). This reaches from strategic traffic planning to splitting a sector well in time before overload can occur. They develop an individual working style that minimises their workload and maximises their thinking time. Therefore, they perceive themselves as highly efficient (six statements).

Risk taking: Older controllers seem to take less risks. They usually go for the safe solutions (22 statements). Despite their working style it is their in-depth knowledge of the current system which makes them safe. They know which features of the system they can rely on and where the possible shortcomings are. They have as well a tendency to distrust all new procedures and technical changes until they see them working. Two of them pointed out to have a sense of responsibility more developed than younger colleagues.

Social aspects: Experience also supports the development of social skills. Many older controllers perceive themselves as more aware of the team and of the reliability of colleagues. Furthermore, they believe themselves to be calmer, more balanced and more relaxed (seventeen statements). They are used to working with people with different working styles and abilities, and therefore have a higher tolerance towards other working styles, and are better able to adapt to different styles. Fourteen interviewees reported to have a higher self-confidence compared to when they were younger.

Handling of unusual situations: Twelve interviewees pointed out that older controllers are better in dealing with non-standard situations. Possibly due to wider experience (e.g. in TWR/APP) they are better in handling emergencies. They stay calm in difficult situations, they know they can get through it, and handle complex traffic calmly. They know the tricks of their job (nine comments). Two controllers believe they are better in decision-making.

Prioritisation: Also linked to management of workload is the adaptation of priorities of tasks (eight interviewees). Older controllers are more selective in their choice which tasks to do quickly and are more aware of the importance of a good prioritisation.

Motivation: Two controllers stated that their high motivation helps them in doing the job; another two mentioned that prior experience with former system changes makes it easier for them to cope with the current demand.

Danger of experience: Experience seems to be not solely beneficial, but can be dangerous, too. Eleven interviewees warned about this downside of experience. To rely too strongly on experience can cause overlooking important new aspects of the situation, falling back on routines can lead people on the wrong path. Furthermore, some ATCOs might become overconfident. Three controllers explicitly referred to the limits of experience.

According to them it can help only up to a certain age to compensate for ageing effects. After the mid-fifties there are definitely declines due to age.

Summary

Impacts on job performance

Areas of impact of ageing
- Slowing down in speed of working
- Increased job demand
- Learning gets harder
- Multitasking and complexity get harder to deal with
- Self-perception changes to the negative

Areas of impact of experience
- Broad memory bank for situations and resolutions
- Increased anticipation
- Better resource management
- Less risk taking
- Social aspects (e.g. higher self-confidence, etc.)
- Better handling of unusual situations
- Better prioritisation
- Higher motivation

7.3.2.3 Experience counteracting age

The question whether experience helps in compensating for possible declines in performance due to age cannot be definitely answered at this stage. As the sections above have shown, the opinions of the interviewed controllers differ with regard to this question.

However, when asked about how they compensate for ageing impacts, many of the controllers mentioned a number of strategies which they apply to cope with the impact of age. Many of those strategies are focused on improving time management as this becomes the critical feature due to slowing down in information processing speed. Better anticipation and planning was therefore brought up by fifteen interviewees. Difficult conflict situations are perceived quicker and the attempt is made to avoid them by solving them early. The automatic retrieval of solutions from memory is another time saving way to work (three comments). Older controllers are able to adapt their workload by doing basic ATC instead of doing things smart. Keeping things simple leaves them more time to think about more complex solutions. This process can be described as falling back on basic experience (like riding a bike). Instead of doing everything they prioritise. Time can be saved as well because well-known information helps interpret new information. Their broad knowledge of situations and solutions (eight statements) is also of help in this process.

The application of an individual working style that suits best for the individual controller may also help in dealing with performance declines (one interviewee). Two controllers stressed the importance of being aware of their own limits. Also a more flexible interpretation of rules and working more carefully (one statement each) were mentioned as supportive. And finally the self-confidence which comes with experience can be a compensating feature (four comments).

When asked about if they believe that older controllers are better in certain tasks, about half of them (32 statements) replied they do not think so. However, twelve interviewees believe they are better as supervisors or other leadership tasks, and seven pointed out they might be better in handling unusual situations like emergencies. Furthermore, they are regarded to be better as instructors and trainers and better in planning tasks (four comments each). One comment each referred to was higher abilities in analysing and higher reliability. Two ATCOs believe the older controllers are generally better because of their accumulated experience. Some interviewees stressed the importance of the team in compensating for performance lows of both younger and older controllers (two comments). More self-confidence and higher self-awareness were cited by two ATCOs as advantages of increased age. Five ATCOs regard individual differences instead of age or experience as relevant, and one sees a dependency from the position.

Summary

Main Strategies for Compensation

- Anticipation and planning
- Automated information processing
- Simple solutions
- Prioritisation

7.3.2.4 Performance curve

For radar controllers there appears to be a reversed U-shaped performance curve over the course of working life. Performance increases steeply throughout the first years after validation, levels off or climbs only slowly further, and starts deteriorating after the age of 45 (22 statements). The optimum age to work radar positions seems to be between 35 and 45 years. In this age span people have both experience and speed (three comments). Younger controllers can ‘fall into traps’ due to their lack of experience, and older controllers (over fifty) are faced with the speed problem. A performance decline towards the end of the career was confirmed by fifteen interviewees, whereas eleven do not see any decline. The onset of decline shows a broad individual variance; comments of the interviewees range from 40 to 52 (six ATCOs).

It seems to be reasonable to suggest an interaction between speed and experience: at the beginning of the career, speed makes up for experience,

later experience makes up for speed. However, after 55 performance definitely decreases. Constant changes (e.g. re-sectorisation) aggravate the situation by counteracting the value of experience. The more things change the more difficult it is to rely on experience.

However, the description above is a simplifying model of performance which cannot cover all aspects. For example, performance does not develop as a steady increase. Instead, controllers have to constantly learn new procedures and have to deal with many kinds of changes. A change of centre especially has a big impact, and in this case the acquisition of experience has to start again from a relatively low level (four comments).

The process of building up experience is most pronounced during the first three to five years after validation, but can be ongoing for the whole duration of working life (thirteen statements).

Some ATCOs referred to the increased demand in their job (thirteen interviewees). For many older controllers it takes an increased effort to keep up a certain level of performance. They experience the job generally as more demanding. However, three interviewees pointed out a seasonal dependency of job demand. When asked about their need for recovery, 27 controllers described their breaks and recovery times as sufficient. Only fourteen have a requirement for more or longer breaks. Seven ATCOs stated that night shifts get more demanding with increased age and require a longer recovery time. Three feel in general more tired.

Again, the role of individual differences was emphasised by a number of interviewees (five statements).

Summary

Average Performance Curve

It appears that the job performance of air traffic controllers follows a reverted U-shaped curve: performance increases throughout the first years after validation, levels off or climbs only slowly further, and starts deteriorating after the age of 45.

7.3.2.5 Influencing factors

Naturally, job performance is not exclusively comprised of individual skills and abilities. There are a number of influencing factors that impact on performance:

- Time spent on position seems to have a major influence on the skills of a radar controller. Thirty of the interviewed controllers mentioned this aspect. As soon as a controller is no longer working hundred percent on a radar position the lack of practice leads to a decline in performance. The most

frequently mentioned causes for this are working as supervisor, working in training or working part-time on other projects.

- The kind of task to be carried out has an influence on how strongly ageing impacts get noticed. Seventeen ATCOs cited that the radar position is more affected then the planner/coordinator function.

- The third major influence is the increase in traffic load and complexity (eleven statements). As mentioned earlier this impact of job demand can hardly be separated from 'pure' ageing impacts. Some of the interviewed controllers stated, that with further increasing traffic levels the ATCO's job might become a younger persons job.

- Also, time spent in a centre (three comments) and the introduction of a new system (two comments) can have an influence of job performance.

Summary

Influencing Factors

- Part-time work
- Radar position
- Traffic load
- Time spent in a centre

7.3.3 What can be expected for the transition to the new system?

7.3.3.1 Areas of concern

In the six centres represented in this study the situation differed with regard to the implementation of a new system. In four of the countries (Sweden, UK, The Netherlands, and Portugal) the transition to the new system was still ahead in time. In Hungary the new system had been introduced about one year ago. Furthermore, the centres differed with respect to the degree of novelty the new system will represent. In one centre, mainly interface aspects will be changed in the near future. In all the other centres, apart from the interface, central functions of the working position will get changed. All of them will have or have already a version of electronic datalink. Some centres will have or have additional automated tools like conflict detection (e.g. Medium-Term Conflict Detection [MTCD]), windows-based applications on the screen and, of course, new input devices, mainly mouse and keyboard.

Depending on the briefly described differences in the new equipment, the attitudes of the concerned controllers show a broad variety. Furthermore, as the transition to the new system has not yet happened in most of the centres, the statements of the controllers about it are often hypothetical. Nevertheless, the expressed opinions and concerns should be taken very seriously as many

of them are backed up by experiences in other ATCCs and human factors research (see also Figure 13).

Acceptance of novelties: Most of the comments during the interviews concerned the acceptance of new concepts (37 statements). ATCOs are often cited to be a conservative population with regard to change (seven statements). This seems to contradict the reality of constant change in their working life (changes in procedures, route structures, sectorisation, etc.). However, it is rather the degree of change which attracts their antipathy. In particular, changes in technical equipment that imply a completely new way of working have to fight for the acceptance by ATCOs. The introduction of electronic Flight Progress Strips (FPS) may serve as illustration. The old paper FPS have been, besides the radar, the main source of information a controller built his or her mental traffic picture on, and a central means to carry out the traffic planning for their sector. The sequencing and order of strips served as a memory aid for time of arrival in the sector, route, special occurrences / coordination demand, etc., and they have been a reliable backup in case of radar failure. Electronic FPS do not only change the way of information acquisition, but also the planning horizon and the way of memorising information. They may even influence the structure of the mental traffic picture. Furthermore, the backup function, in case of a system failure, is no longer guaranteed. It is therefore not surprising that the introduction of electronic FPS was repeatedly mentioned as a challenge in the new system. Similar problems arise with automated conflict alerts, for both short-termed and medium-termed versions.

Interface issues: The second most frequently stated problem area (nineteen comments). Mainly mouse input is in the beginning difficult to get used to. Also the windows concept was criticised by many interviewees, because it sometimes needs too much space on the screen, and it is confusing for those without computer experience. Some controllers dislike the colour coding of their new interface; they find that it decreases the readability or distracts their attention. Generally, the requirement for Information Technology (IT) skills is a concern for older controllers, however mediated by their individual familiarity with computers. For those over fifty without previous experience with PCs, the transition is likely to be more difficult and demanding, and more training time may help them. Many older controllers feel uncomfortable about the increased reliance on computers (eight interviewees).

Increased workload: For some of the controllers (four statements) the new system is expected to increase the workload in the beginning. They believe they are too old (and therefore too slow) to work with the same amount of traffic as in the old system. They are able to cope with complexity when they grow with it, but not if they have to take one big step.

Ergonomic Aspects: A few interviewees (two comments) complained about ergonomic aspects like twisted seating positions, and two ATCOs are concerned with the changes in information distribution (retrieving information spread over various sources).

Positive aspects: Quite a number of statements (twenty) emphasised the positive sides of the new systems. Appreciated are e.g. the increased availability of information, the additional safety nets in form of conflict alerts, and even electronic FPS. Some aspects are especially helpful for the transition, like experience with computers, involvement in system development, and participation in simulation trials at the EUROCONTROL Experimental Centre (EEC) in Brétigny, France. Eight controllers believe the transfer of experience from the old system would be easily possible. Their routine in dealing with the traffic could provide them with some free capacity to handle the unfamiliar system.

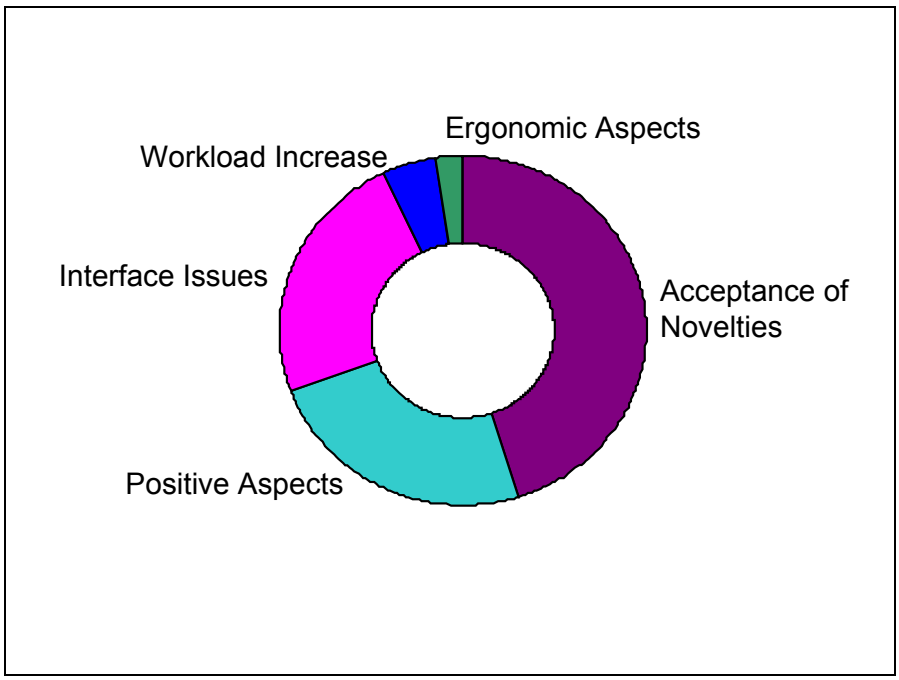

Figure 13: Frequency of issues for acceptance of new systems

Summary

Concerns for system transition

For many controllers it appears to be difficult to accept new concepts. This is even more the case if they cannot see the possible benefit of a new system. Interface issues are of high importance. The transition might be more difficult for these controllers who are not computer-literate. An increase in workload is concerning for some controllers.
The positive aspects of a transition are highly appreciated by many controllers.

7.3.3.2 Teamwork

Assuming that younger controllers are on average more 'computer literate' as their older colleagues, the question was put whether this could lead to tensions in teamwork. However, the majority of controllers does not expect this to be the case (43 statements). Only fourteen see the potential for team conflicts. Four stressed the influence of individual personalities on this issue.

7.3.3.3 Training requirements

Twenty statements of the interviewees addressed training issues. On the positive side, practical training in simulators and shadow mode sessions as well as the availability of Computer-based Training (CBT) was highlighted. On the negative side delays in the training programmes were referred to, making refresher training necessary. The presentation and amount of theoretical information about the new system is another critical feature (thirteen statements). The higher requirements for technical background knowledge are more problematic for older controllers as it is exactly this kind of knowledge that gets more difficult to acquire with increased age. However, the most concerning aspect is the huge amount of information and the combination of changes in almost all aspects of the job that causes a high demand on the learning capacity of people.

The opinions about training requirements are widely spread as the training has not yet started in some of the centres. When asked about if older controllers should get more training time, 25 controllers agreed. They believe that it might take older controllers longer to learn the new system. However, additional training time is regarded as very helpful not only for older controllers as many of the younger ones are expected to struggle as well. An individual adaptation of training time would be appreciated (fourteen comments). Thirteen of the interviewees do not see a requirement for more training time for older controllers. Some of them even regard it as a prejudice to assume they would need more time. A number of ATCOs (six statements) do not have an opinion on this question, three pointed out the dependency on familiarity with computers, and two highlighted motivational issues.

7.3.4 Other influencing factors

What else could influence the job performance of an ATCO? 41 interviewees stressed the importance of motivation. Most controllers report on having a high intrinsic job motivation, i.e. the job as such, the confidence of doing a good job, is highly rewarding for them. Many controllers (22 statements) talked about the role of management for their motivation. Management has the power of having a strong influence on staff motivation, however, unfortunately the impact seems to be mainly negative. Quite a number of controllers suffer from demotivation because of various managerial decisions. Another important source of influence is the private background of controllers (fifteen comments). The family situation can have an impact in both directions, if everything is well at home the job performance may be supported, but in case of severe family problems (e.g. the death of a partner) the job may suffer, too.

Ergonomic aspects (seven comments) can have obviously an impact on job performance, for instance if the lighting conditions make it harder to read. Some controllers mentioned the move to a new room because of the new system as very positive and big improvement in their physical working conditions. Five controllers referred to their team as another supportive factor. Similarly, three ATCOs cited change in general as a source of motivation. One controller brought up the shift system as positive aspect in his job, because it allows for flexibility. Another one pointed out the responsibility of the job as motivating, and one mentioned good salary as positive factor.

A more negative impact is recognisable for health problems (five statements), and traffic load (four comments). Both overload and too low traffic levels are a possibly negative state. The lack of career alternatives was cited by two controllers as unsatisfying. Staff shortage was mentioned by one ATCO as a problem.

For the transition to a new system some factors are highlighted in importance. The remaining time until retirement is a critical feature: the closer people are to their retirement, the less motivated they are to succeed in the transition (five statements). Furthermore, attitude towards change is important in this context (four interviewees). With a positive attitude it may be easier to motivate yourself for the transition. Additionally, the way in which transition training is provided can impact on motivation (four comments).

7.3.5 Expectations towards management

The main issue controllers would like to see being addressed by their management is career development (sixteen statements). Opening career alternatives for these controllers who do not want or cannot keep their validations any longer is essential. Training issues were the second most mentioned expectations (seven comments). They range from requiring more emergency training, better English training, better simulation equipment and more simulator training, to individually adapted transition training. Six controllers suggest to the management to support the motivation of staff, especially older controllers. They should communicate the message that older controllers are welcome and important in operations. Furthermore, motivation for system transition needs explicit support from management. Six ATCOs doubt whether management takes operational staff serious and see room for improvement in this regard. Better staffing to avoid overtimes for the current staff was mentioned by four controllers. Two interviewees would like to see the pension system improved. Two controllers stated their management completely neglects the issue, and one sees the issue primarily being addressed and solved in the OPS room. One controller asked for adaptation of retirement age, for better integration of older controllers in system development and for a change in the means of information distribution.

7.3.6 Expertise

The question in the interview guideline addressing expertise of controllers was originally aimed at identifying differences in work behaviour between new

controllers to medium experienced and highly experienced controllers. However, it appears this question was asked in too broad a sense and therefore resulted in a list of desirable characteristics of controllers. Even if this list does not answer the original question, it may be of interest for people involved in controller's selection.

Below is the top-ten list of desirable characteristics of ATCOs:

1. Social skills, team skills (53 statements).
2. Stress resistance, calmness (39 statements).
3. Flexibility (24 statements).
4. Motivation (23 statements).
5. Decision-making skills (22 statements).
6. Basic skills (such as job-related knowledge, natural ability) (21 statements).
7. Intelligence/education (20 statements).
8. 3-D thinking (19 statements).
9. Concentration (13 statements).
10. Confidence (13 statements).

The remaining nineteen characteristics in this list may not be of less importance than the above-reported ones. They were simply mentioned less frequently by the interviewees. These are listed below, in the sequence of frequency they were cited:

- multitasking,
- problem solving,
- reliability,
- basic fitness,
- communication,
- planning,
- risk taking,
- English skills,
- adaptability,
- being extraverted,
- having a sense of humour,
- being well organised,
- good anticipation skills,
- experience,
- being open-minded,
- self-awareness,
- fulfil the selection criteria,
- be in time,
- abstract reasoning.

8. PERSPECTIVES FOR THE FUTURE – WHAT NEEDS TO BE DONE?

This report attempted to provide an introduction into the issues associated with ageing of air traffic controllers. The solid evidence for declines in many mental functions with increasing age cannot equally be found for job performance. However, the interviews conducted with 76 controllers between the age of 39 and 63 years confirm that the job of air traffic controllers is vulnerable for ageing impairments.

Still, one could ask why it should be necessary to act on this situation. The past did not reveal any serious problems with regard to ageing controllers. However, today's situation differs in many respects from the past. Two main areas of concern make it necessary to deal with the issue: the first one is the staff shortage encountered by most European ATC services and the second one is the forthcoming or already executed introduction of automated systems in ATC.

Some older controllers who are faced with a technical system transition may have the feeling they do not want to be part of this transition. From anecdotal evidence it is known that during each transition a certain percentage of older controllers takes the option of early retirement. No figures are available to classify this trend; however, estimates range form two to five percent loss of the total workforce due to early retirement. In the current situation with severe staff shortage, even two percent is a too high number.

Associated with manpower planning is also the age structure of the controller population. Data from the United States show that the largest number of American controllers is currently in the age group between 31 and 39 years[45]. In ten to fifteen years time this group will be in their forties and fifties. The majority of controllers will therefore be in an age range where the chance of suffering from a performance decline is increased. For Europe no statistics on the age distribution of the controller workforce is available. Considering the severity of the problem it is highly recommended to address this lack of data.

The introduction of automated systems could be a turning point in different directions. In the worst case it could compound the situation for ageing controllers. In the best case it could be highly supportive for them. Automated systems become not inevitably a success. It needs preparation and careful consideration of many factors to gain acceptance by controllers. Both in the design phase and in the implementation phase of a new system input from operational and human factors experts is beneficial.

However, currently we still lack the required knowledge to be able to provide useful advice for system design for older controllers. The first step would be to conduct an experimental project to exactly classify the changes of controller's performance with age, be in a positive direction due to experience or in a negative direction due to ageing. Interviews provide only subjective data and

[45] Becker & Milke (1998)

in many areas of cognitive functions they remain vague because most mental processes are unconscious. Based on solid experimental data it would be possible to examine the design of automated tools in the light of this data. Only than and only in close cooperation with operational staff and system designers an improvement of system and tool design could be achieved.

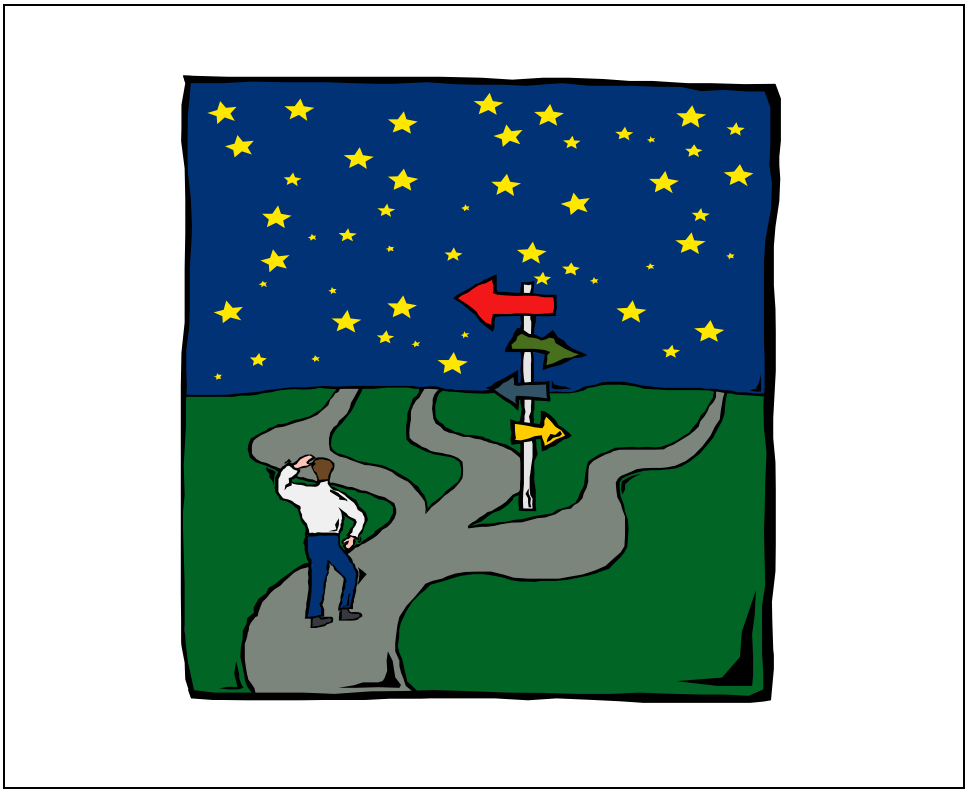

Figure 14: Where will automation lead?

Even optimally designed? new equipment may still meet resistance by controllers. The implementation of a new system is always embedded in a process of change management, whether this is an actively managed process or just a ‘let’s see what will come’ approach. This process of transfer from an old system to a new one can be handled in many different ways. The bigger the step will be and the more aspects of work are to be changed the more important it becomes to efficiently manage the transition.

Management has an important role here. Good communication is a prerequisite to get employees committed to change. It should be clearly explained why a change is necessary, which consequences it will have for the individual and how big the effort for the employees can be expected to be. Already at an early stage management should send the clear message that the expertise of older controllers is valued and they will receive all necessary support to succeed in the transition. Including controllers of all age groups into the development and design of a system is highly recommendable. Also a working group for change management including operational people could be a way to achieve a smooth transition.

During the implementation phase of a new system the transition training can contribute considerably to the success of a new system. Its actual set-up could facilitate the transition for older controllers. Currently it is difficult to determine what exactly their requirements would be. However, the interviews give already some hints about what could be useful. Examples are allowing for flexible training time, providing sufficient possibilities for practical training and providing additional computer courses if necessary. A more systematic approach to improve transition training would be recommendable.

Another aspect which was touched upon in this report is the medical status of older controllers. Accumulated health consequences of shift work are a serious problem and should be looked after. For a start it might be useful to develop a simple guideline with health advice for operational staff, including simple recommendations for diet, exercise and sleep hygiene. Furthermore, in-depth examination of the issue may be required.

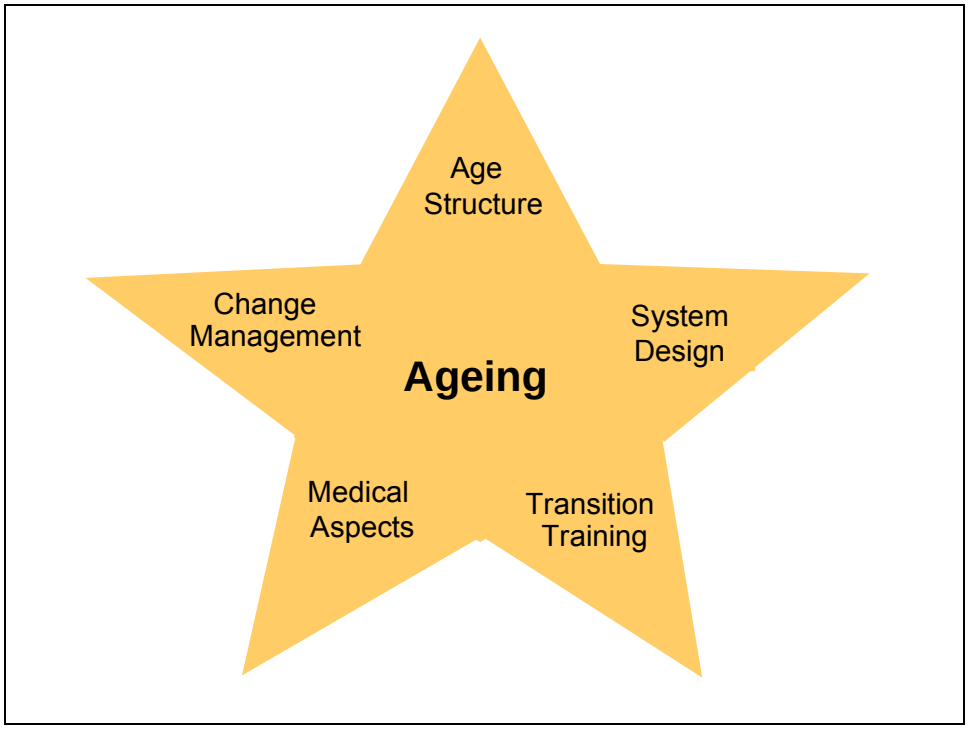

Figure 15: Areas of further investigation within the scope of ageing in ATM

Where do we go from here? It should have become obvious that ageing is a broad subject, requiring a consolidated effort from various areas and different levels of organisational hierarchies. Human factors, training and manpower planning issues are highly interrelated when it comes to ageing. To achieve an improvement of the present situation input from all three areas is absolutely necessary. Also all hierarchical levels of an organisation have to cooperate to successfully integrate older employees in day-to-day work.

Higher management plays an essential role in defining a general philosophy of good information, knowledge and expertise transfer between generations.

Management at all levels carries the responsibility for appropriate manpower planning, career development, training and actual working conditions in the OPS room. Management in the OPS room directly takes care of the situation of older ATCOs. This is done already today, but the conditions under which staff management has to be done could be improved by actions on higher levels.

Finally, it will be the team of controllers which has the power to support each individual according to his or her needs. Every ATCO has strengths and weaknesses and the team is the entity to balance and find satisfying solutions for possible changes in individual abilities. An increased awareness of possible problems related to ageing may help the younger part of the workforce to better understand and accept their older colleagues. For the older controllers themselves it may be helpful to know that they are undergoing a natural development and almost everybody is faced with similar problems from a certain age on.

It was stated repeatedly in this report, but it is worth stressing it again: improvements will be beneficial to controllers of all age groups. Better change management, enhanced system design, adaptable transition training, improved manpower planning and career development will facilitate all controllers' situation, even if they may be more beneficial to older ATCOs.

Summary

The issue of ageing in ATM should be addressed before it gets critical. A consolidated effort by manpower planning, training and human factors is necessary to cover the scope of this subject.

All hierarchical levels of an organisation should cooperate to achieve satisfying solutions for ageing controllers.

Some measures are recommendable to tackle the situation:

- European-wide data on the age structure of the operational workforce should be collected to assess the severity of the problem;
- a concept of proactive change management should be developed to support units in the process of system transition;
- experimental data on controller's job performance is necessary to provide useful input to system design;
- a concept for adapting transition training to the requirements of older controllers should be developed;
- it should be considered to initiate some work on the medical status of older controllers, as the effects of ageing and shift work are a health-critical combination.

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ABBREVIATIONS AND ACRONYMS

For the purposes of this document the following abbreviations and acronyms shall apply:

ACC	Area Control Centre
APP	Approach Control
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATCO	Air Traffic Control Officer / Air Traffic Controller *(UK/US)*
ATM	Air Traffic Management
ATST	Air Traffic Scenario Test
CBPM	Computer-based Performance Measure
CBT	Computer-based Training
DAS	Directorate ATM Strategies *(EUROCONTROL Headquarters, SD)*
DAS/HUM *or just* HUM	Human Factors Management Business Division *(EUROCONTROL Headquarters, SD; formerly known as 'DIS/HUM' or just 'HUM')*
DIS	Director(ate) Infrastructure, ATC Systems and Support *(EUROCONTROL Headquarters, SDE)*
DIS/HUM *or just* HUM	Human Factors and Manpower Unit *(EUROCONTROL Headquarters, SDE; formerly stood for 'ATM Human Resources Unit'; now known as 'DAS/HUM' or just 'HUM')*
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme *(now EATM(P))*
EATM(P)	European Air Traffic Management (Programme) *(formerly EATCHIP)*
EEC	EUROCONTROL Experimental Centre *(Brétigny, France)*
ET	Executive Task *(EATCHIP)*

FAA	Federal Aviation Administration *(US)*
FPS	Flight Progress Strip(s)
GUI	Guidelines *(EATCHIP/EATM(P))*
HFFG	Human Factors Focus Group *(EATM, HRT; formerly known as 'HFSG')*
HFSG	Human Factors Sub-Group *(EATCHIP/EATMP, HRT; now known as 'HFFG')*
HRS	Human Resources Programme *(EATM(P))*
HRT	Human Resources Team *(EATCHIP/EATM(P))*
HSP	Human Factors Sub-Programme *(EATM(P), HRS)*
HUM (Domain)	Human Resources (Domain) *(EATCHIP/EATMP)*
IT	Information Technology
MSP	Manpower Sub-Programme *(EATM(P), HRS)*
MTCD	Medium-Term Conflict Detection
OJT	On-the-Job Training
OPS	Operations
REP	Report *(EATCHIP/EATM(P))*
SD	Senior Director, EATM Service Business Unit *(EUROCONTROL Headquarters; formerly known as 'SDE')*
SDE	Senior Director, Principal EATMP Directorate *or, in short,* Senior Director(ate) EATMP (*EUROCONTROL Headquarters; now known as 'SD')*
SHAPE (Project)	Solutions for Human-Automation Partnerships in European ATM (Project) *(EATM(P), HRS, HSP)*
ST	Specialist Task *(EATCHIP)*
TWR	Aerodrome Control (Tower)

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Carine Hellinckx
(External contractor)
EUROCONTROL Headquarters, DAS/HUM

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