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Age, Experience and Automation in European Air Traffic Control - Survey in the ECAC Area

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Abstract

This document describes a survey conducted in the European Civil Aviation Conference (ECAC) Area on the issue of age, experience and automation in European Air Traffic Management (ATM). It provides the theoretical background of the survey, based on cognitive ageing and expertise research. The methods applied and the evaluation process are explained, and the results detailed. Four groups of results are depicted: context factors, cognitive ageing versus gains due to experience, job demand and strain, and ageing and technological change. On basis of the results key elements of ageing in ATM were identified. These are the cognitive skills of Air Traffic Controllers (ATCOs), which are most likely to change because of ageing or experience. The final section develops scenarios on how best to deal with the issue of ageing in ATM in the future.

The report has been prepared as part of the 'Solutions for Human-Automation Partnerships in European ATM (SHAPE)' Project being carried out 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)'. It is the second report of SHAPE Work Package 'Age and Experience'. The first one, published in 2003 (see EATM, 2003a), contains a literature review about known positive and negative effects of ageing on human performance. It discusses the relevance of these aspects for the European ATM environment.

Keywords

Cognition	Ageing	Change Management	Skill Set Changes
Expertise	Questionnaire	Automation	Job Demand

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0.1	07.04.2003		Working Draft for HFFG9	All
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1.0	20.08.2004	040201-11	Released Issue (agreed on 28-29.01.2004) (final document configuration and editorial adjustments)	All

CONTENTS

EXECUTIVE SUMMARY

This report is concerned with the relation of age, experience and automation. It is the second report of the Work Package 'Age and Experience' of the project entitled 'Solutions for the Human-Automation Partnerships in European ATM (SHAPE)' being carried out by the Human Factors Management Business Division (DAS/HUM) formerly known as 'Human Factors and Manpower Unit (DIS/HUM)'.

The document describes a survey performed in the ECAC area about the positive and negative effects of ageing as perceived by controllers of European Air Traffic Control Centres (ATCCs). The survey resulted in key elements of ageing in operation, and in scenarios on how best to deal with the issue of ageing in future ATM.

Section 1, 'Introduction', provides the purpose and scope of this document, and the SHAPE Project background.

Section 2, 'Approach', describes the methodology applied to the survey. It outlines the questionnaire on which the survey is based, and the process and means used for its distribution. Furthermore, it gives an overview of the subjects who participated in the project. The last part covers the data evaluation.

Section 3, 'Results', provides the results of the data evaluation. This section includes the following sub-sections:

- 3.1, 'Evaluation Preparation', gives the results of several cluster analyses conducted as preparation for the further data evaluation;

- 3.2 to 3.5 describe the outcome of the data evaluation:
  - 3.2 is concerned with 'Context Factors' for ageing in ATM,
  - 3.3 details the results on 'Cognitive Ageing versus Gains due to Experience',
  - 3.4 depicts the outcome regarding 'Job Demand and Strain', and
  - 3.5 outlines the results concerned with 'Ageing and Technological Change'.

Section 4, 'Key Element Identification', applies the findings from the data evaluation and from a literature review to a list of controller's cognitive skills. The impact of ageing and experience on these cognitive skills is determined. The skills, which will change to the positive or negative, are regarded as the key elements of ageing in ATM.

Section 5, 'Scenario Development', details some possible approaches to the issue of ageing in ATM.

Section 6, 'Conclusions', summarises the outcomes of the survey and concludes on necessary actions.

The Appendix to this document consists of the questionnaire used for the survey.

Technical appendices providing a detailed description of the statistical tests, gathered in a separate document entitled 'Age, Experience and Automation in European ATC – Survey in the ECAC Area: Technical Supplement', can be obtained upon request[1].

[1] For contact details see pages ii and iii of this report.

1. INTRODUCTION

1.1 Purpose

The purpose of this document is to provide the results of a survey conducted in the ECAC area on the issue of 'Age, Experience and Automation in European ATC'. It addresses all ATM services - Aerodrome Control Tower (TWR), Approach Control Centre (APP), Area Control Centre (ACC) and Oceanic.

This survey aimed to secure results from an initial interview study on the subject. Furthermore, with the support of this survey, key elements in relation to ageing and automation in ATM are identified. Each of these key elements may have a certain impact on the overall performance of a controller. Based on its findings, this report explains the link between the revealed key elements and the cognitive effects of ageing. The latest scientific work in this area will help to explain these interactions between age and cognitive activities of Air Traffic Controllers (ATCOs).

The overall objective of this work is to develop scenarios of appropriate compensation strategies regarding the issue of ageing in ATM. A number of scenarios are possible, taking into account the areas where compensation is necessary because of decline due to age and those where experience could be a source for such compensation strategies. Training, working procedures and technical equipment design are obvious areas in this context.

1.2 Scope

This report describes the questionnaire development, the process and means used for its distribution, and its evaluation and results. The identification of key elements builds on these results and provides the prerequisites to develop scenarios for possible compensation strategies.

The survey includes returns from 1079 controllers throughout the ECAC area. The returns are all confidential and were treated anonymously.

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) (see EATMP, 2000) conducted by the Human Factors and Manpower Unit (DIS/HUM) of EUROCONTROL, today known as 'Human Factors Management Business Division (DAS/HUM)'.

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, which 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 EATM, 2003b, 2003c, 2003d).

- 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 EATM, 2003e).

- 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 (see EATM, 2004a).

- 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 (see EATM, 2004b).

- 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 (see EATM, 2004c).

- 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 (see EATM, 2004d).

- 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 and EATM, 2003a).

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 compiled in a framework in order to assist the user in assessing or evaluating the impact of new systems on the controller performance, efficiency and safety. This framework will be realised as a computerised toolkit called the 'SHAPE Toolkit' and is planned to be available later in 2004.

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2. APPROACH

2.1 Introduction

This section provides the methodological background of the survey. It outlines the questionnaire on which the survey is based, and the process and means used for its distribution. Furthermore, it gives an overview of the subjects who participated in the project. The last part covers the data evaluation.

2.2 The Questionnaire

Based on an interview study conducted in Spring 2001 by the EUROCONTROL Human Factors and Manpower Unit (DIS/HUM), since renamed 'Human Factors Management Business Division (DAS/HUM)', a questionnaire addressing the areas identified as relevant through the interviews was developed. The questionnaire was built in such a way that data on subjective experience of controllers of all age groups could be collected, in order to allow statistical comparison of age cohorts. The questionnaire took possible intervening variables into account, such as previous work experience, proportion of part-time work, actual work positions and average workload. All these factors could be indeed expected to interact, to a high extent, with possible age effects.

Taking the broad scope of the questionnaire into account, the question format varied depending on the kind of information to be gathered. A combination of open answering format and multiple-choice questions and ratings turned out to be most suitable to fulfil the requirements. Since most users had a native language other than English, it was decided that basic English would be used for the questionnaire, and that psychological jargon and sophisticated wording would be avoided. As ATCOs are renowned to be busy people, the average time to complete the questionnaire did not exceed 45 minutes. Desirably, it should have taken less time. However, as the level of proficiency in English varied from user to user, the time needed to complete the questionnaire unavoidably varied accordingly.

The development of the questionnaire was an iterative process with repeated feedback loops. Based on the interviews all potentially relevant areas were identified and brought into question format.

The first draft version of the questionnaire was presented to the Human Factors Sub-Programme (HSP) Team of DIS/HUM, and first feedback received was included in the following version. The version so revised was distributed via the Human Factors Sub-Group (HFSG) of the EATMP Human Resources Team (HRT), now known as the Human Factors Focus Group (HFFG), to about fifty operational controllers in EUROCONTROL Member States. The controllers were asked to provide feedback on areas such as

how clear the instructions for using the questionnaire were, how easy to understand the questions were, the usability of the rating scale, whether the ATC terminology used in the questionnaire was correct, how long it took them to fill in the questionnaire, and whether any important aspects were missing.

The first trial with operational people resulted in very valuable feedback and led to further improvement of the questionnaire. Finally, the HFSG Members were asked to give their comments, which were also included. The questionnaire then received a final check by a number of ex-controllers working in DIS/HUM.

Two versions of the final questionnaire, hard and soft, identical in content, were developed. Hard copies were sent to, and sent back by the target people by mail, while the interactive electronic version, in MS Word, was distributed by e-mail and uploaded on the EUROCONTROL Human Factors Web site. Replies were received by e-mail. The final paper version is appended to this report.

The questionnaire covered the following topics:

- Introduction to the project, including the scope and objectives of the project, and the instructions to complete and return the questionnaire.
- Personal data on the controller's background (treated anonymously), like current workplace, gender, age, etc. This section also included questions about the previous work experience, licences, preferred sectors, non-operational tasks, etc., as all these topics were likely to interact with, or impact on, job performance and experience.
- Technological system change, addressing the positive and negative aspects of system transition.
- Transition training.
- The impact of age and experience on job performance.
- Possible intervening variables as perceived by the controllers (that is a subjective assessment of influencing factors).

As already pointed out earlier, the question format varied depending on the material to be gathered. For further details see the Appendix to this report.

2.3 Distribution and Return of the Questionnaire

2.3.1 Distribution

To maximise the efficiency of distribution and return of the questionnaire a number of supplementary actions were taken:

- HRT was approached to seek for support of the questionnaire distribution and forward it to their national Air Navigation Service Providers (ANSPs);
- in parallel, HFSG was also invited to distribute the questionnaire within their range of responsibility;
- finally, the most direct approach was taken by contacting the ATC units directly, for which EUROCONTROL's Central Flow Management Unit (CFMU) provided an address list via their Web site;
- in addition, the representative in HFSG of the International Federation of Air Traffic Controllers' Associations (IFATCA) offered to distribute the questionnaire via official IFATCA channels.

It was obvious that the combination of all these distribution channels would allow to reach more operational controllers than if only one of them were used. This parallel approach therefore appeared to be the most promising.

The target addressees were the shift or watch supervisors in ATC units. Cooperation with supervisors was favoured whenever possible as these were expected to have the most direct influence on operational controllers (i.e. the target group of the questionnaire) and were most likely to achieve the commitment of their colleagues. Every 'survey package' to be sent to the units therefore consisted of a letter addressing the supervisor and explaining the purpose of the survey, an A3 poster to be put up in the ops room to 'advertise' the project, and a set of questionnaires to be handed out to the controllers. Responses (i.e. the completed questionnaires) had to be collectively returned to DIS/HUM through local operational or shift/watch managers.

2.3.2 Return

1079 questionnaires from 28 countries were returned: 463 (42,91%) by e-mail and 616 (57,09%) by correspondence. Distribution of the questionnaire by e-mail and via the Internet turned out to be a successful way of gathering data.

The 1079 returns represent 6,39% of the ECAC controller population[2]. For optimal representation a return rate of 10% would have been ideal. However, a value between 5 and 10% can be regarded as satisfactory. It should be taken into account that the return rate varied substantially between the participating countries. Ten countries had a return rate below 5%, five between 5 and 10%, and ten between 10 and 55%. For three countries the rate could not be calculated due to missing baseline. 107 returns were not related to a specific country because the responding controllers did not complete the required data.

[2] Data from the fifth Performance Review Commission (PRC) Report for the year 2000.

The 1079 questionnaires were entered into a database in Excel format. Due to the coding process required for the database, the final number of variables was 134 (for the complete list see Table B1 in Technical Appendix B): 33 were text variables, used for all the questions with open answering format and for other information requiring text input, 32 were coded binary, that is they were assigned the value zero or one, and 53 of the variables were coded on ordinal level, that is they used the rating scale from one to six. The remaining sixteen variables had an interval data level. Depending on the scale level of the data different means for evaluation were required.

2.4 Subjects

1079 ATCOs from 28 countries participated in the survey. The average age of the subjects was 38,17 years, with a standard deviation (std) of 8,94. The youngest controller in the sample was 21 years old at the time of the survey, the oldest controller was sixty. The age distribution is displayed in Figure 1. Detailed data can be found in Tables C1 to C3 in Technical Appendix C. The age distribution of our subjects has a double peak, the first around the 30-35 age group and the second one around the age of 45-50. In between, there is a dip, meaning that there are less controllers in the 35-45 age group. This may reflect a controller shortage in the past subsequent to interruptions in the recruitment process. The low number of controllers under the age of thirty may also be an indicator of a controller shortage in the near future. However, this data should be interpreted with care as it does not represent the overall controller population in Europe.

196 of the 1079 controllers who returned the questionnaire are female (18,2%), 879 are male (81,5%), and for four others the data is missing.

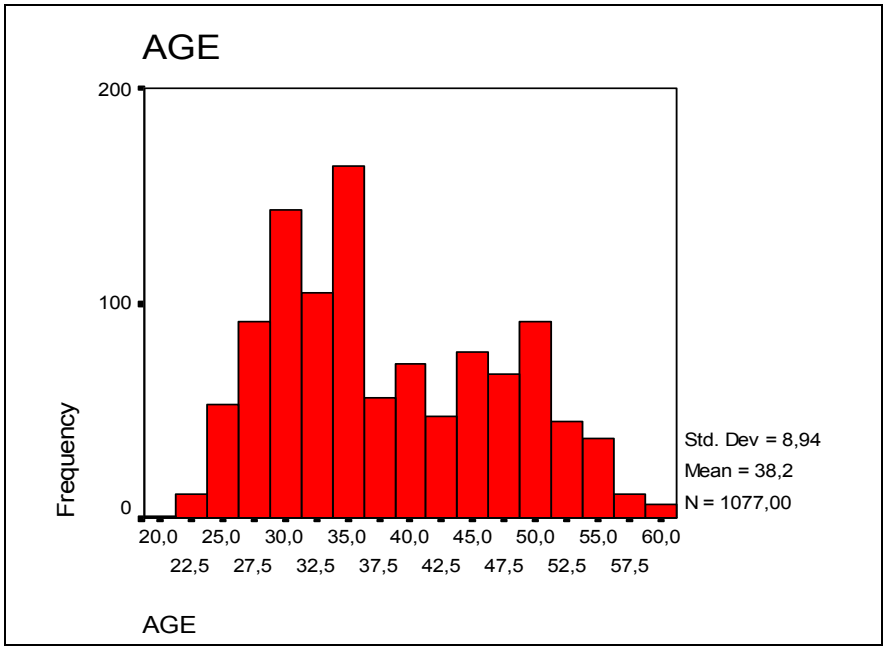

Figure 1: Age distribution of the sample of 1079 air traffic controllers

The controllers questioned have a job experience on their current position of 121 months on average, that is slightly above ten years. Standard deviation is 97,16 months, the maximum is 408 months and the minimum zero month. Details can be found in Tables C4 and C5 in Technical Appendix C.

The distribution for the experience on the current positions is presented in Figure 2 below. As can be seen, most of the controllers in our sample have an experience of two years (ninety cases). One or three years of experience are the second largest categories, with 78 cases for either duration. The majority of controllers have between one and ten years of experience (648 cases). 258 controllers have a job experience on their current position of ten to twenty years. There are 138 controllers in the group having an experience of twenty to thirty years on their current position. Seventeen controllers in this survey have more than thirty years of experience on their current position. The longest experience is 34 years.

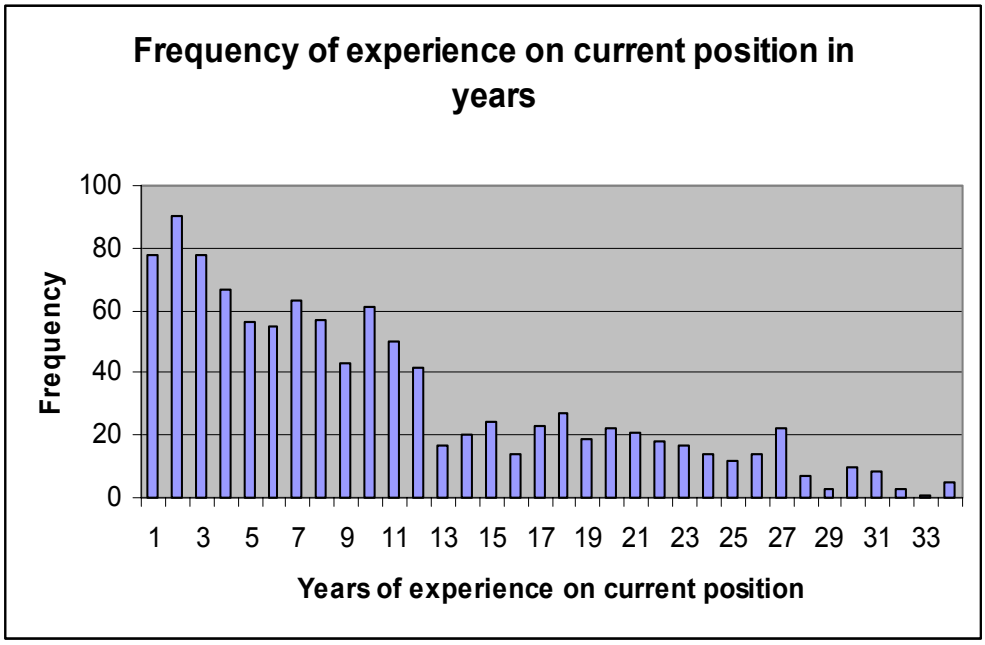

Figure 2: Experience on the current position in years for 1079 ATCOs

The distribution of the subjects over ATC services is depicted in Figure 3 overleaf:

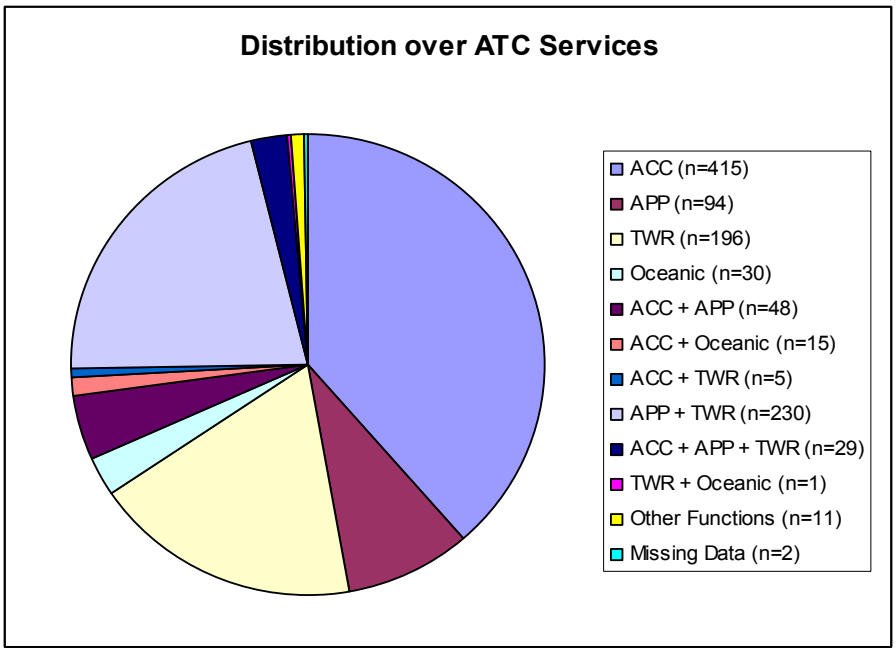

Figure 3: Distribution of the 1079 participating controllers over ATC Services

From the 1079 ATCOs 415 work in an Area Control Centre (ACC), 94 in Approach/Departure control (APP), 196 in a Tower (TWR), and thirty in an Oceanic Centre. Even though there is a number of controllers who work in one single service, many ATCOs perform their duties in combined ATC services. 48 controllers work both as ACC and APP. Fifteen combine ACC and Oceanic, five ACC and TWR, and 230 ATCOs switch from APP to TWR. 29 combine ACC, APP and TWR services, while only one ATCO works both in Oceanic and Tower control, and eleven have other functions. For two people the data is missing.

2.5 Evaluation

2.5.1 Introduction

This section provides the background of the evaluation process, and the approach taken. It formulates the leading questions, outlines the underlying variables and the carrying out of the evaluation. The statistical criteria applied to the evaluation are also depicted. The section closes with a preview on Sections 4 and 5 of this report, dealing with the interpretation of the results and the conclusions drawn from them.

Note: To better identify the variables in the flow of text, the variable names will be printed in *italic* throughout the report.

2.5.2 Leading questions

The work so far conducted in the area of ageing and ATM points the way to some central aspects which build the focus of the data evaluation. Both scientific research and the information from the interviews with operational controllers contributed to the formulation of these leading questions. The following aspects provide this basic structure for the evaluation[3]:

- Context factors: The processes related to ageing do not happen in isolation. They are embedded in the overall working environment. In some situations the negative impacts of ageing can be felt more strongly, while, under other conditions, it is easier to cope with them. The factors likely to have an interaction with age are *Kind of ATC Service*, *Part-time Work*, *Current Position* (e.g. radar/executive position or planning position), and many others. Detailed results concerning context factors can be found in Section 3.2 of this report.

- Cognitive ageing versus gains due to experience: We have to assume that, for each one, a number of cognitive declines are unavoidable with increasing age. Vision, hearing and overall attention get worse, tasks highly demanding for working memory become more difficult, and declines can be also found in spatial reasoning and some aspects of problem solving. However, research concerning job performance does not confirm a general decline of job performance with age. Possibly the compensating power of experience helps to keep up performance. The characteristics of expertise are structured, principled knowledge, proceduralised knowledge, skilled memory, automaticity, effective problem representation and strong self-regulatory skills. The results related to this group of questions will be described in detail in Section 3.3 of this report.

- Job demand and strain: Physiological studies on health, stress, and job demand and strain confirm a close link between these factors. From many areas of research it is also a well-known fact that health problems increase with age. Interactions between age, health and stress/strain have already been proven for some aspects of professional live already, for example for shift work. Therefore, in Section 3.4 of this report the data evaluation will take a closer look on the interaction of age and stress/strain.

- Ageing and technological change: The introduction of new technology in European ATM is the starting point of this survey. The sophisticated computerisation of ATC equipment implies a challenge for most controllers of all age groups. In addition, technological change always bears the danger of outdating expertise. For this reason it has to be assumed that older controllers will be hard hit by radical technological change as they might have to rely on their experience to compensate for

[3] For further details on these aspects see also EATMP (2003a).

ageing impairments. The 'ageing and technological change' topic will be analysed in depth in Section 3.5 of this report.

Section 3, 'Results', is structured along the above four key questions, starting with the 'context factors', proceeding with 'cognitive ageing versus gains due to experience' and 'job demand and strain', and closing with 'ageing and technological change'.

2.5.3 Variables underlying the leading questions

Throughout all the evaluation questions, *age* of the controllers is the independent variable. It is not used as independent variable in a strictly experimental sense (obviously the age of the participating controllers cannot be 'varied' by the author of this survey). *Age* is rather regarded as a variable influencing the dependent variables that are detailed further down in this report. As mentioned earlier, a total of 133 variables was extracted from the questionnaire. Not all of the variables are useful for the evaluation. For example, *code number* of the questionnaire is only used for the internal coding of the data. The variables included in the evaluation are listed below along the four main categories, 'cognitive ageing versus gains due to experience'; 'job demand and strain'; 'ageing and technological change' and 'context factors'. Further explanations will be given in the respective sections on the evaluation results.

37 variables contributed to the exploration of the questions related to 'cognitive ageing versus gains due to experience'. Table A1 in Technical Appendix A lists the variables and the section of the questionnaire dealing with the corresponding questions. The seven variables which underlie the topic 'job demand and strain' are listed in Table A2 in Technical Appendix A. The area of 'ageing and technological change' is addressed by 27 variables that are listed in Table A3 in Technical Appendix A. Finally, 39 variables are taken into account as possible 'context factors'. Table A4 in Technical Appendix A provides the list of these influencing variables.

2.5.4 Evaluation process and statistical criteria

All statistical analyses were calculated using the Statistical Package for the Social Sciences (SPSS) for Windows, Version 10.0. For graphs and simple calculations Excel 2002 was used.

As a first step a number of cluster analyses were conducted to screen the data for interactions amongst the variables. Additionally, the cluster analyses served the purpose to retrieve sensible cut-off points for the age groups in the overall sample. The cluster analyses are described in further detail in Section 3.

The next step consisted of descriptive and inferential statistical evaluations of the data. The descriptive evaluations are mainly frequency counts, means

and standard deviations of sub-samples, and minimum and maximum values. The median was only interested in a limited number of questions.

The inferential statistical evaluations were adapted to the questions and the level of the data:

- Correlations were calculated using Pearson correlation for interval data, Kendall's tau for interval and ordinal data, and Eta for binary and interval data.

- Mean differences were checked for significance. Analysis Of Variance (ANOVA) was performed for interval data, subsequent Tukey-HSD tests were used for more than two groups, and Mann-Whitney U-test was used in case of two groups. Kruskal-Wallis-test and Chi^2-tests were used in case of more than two groups, respectively for ordinal data, and for binary and categorical data. The levels of significance are defined in accordance with the standard level (5%) or 1% for highly significant differences.

- For interactions between independent variables (factors) analysis of variance for two factors was used. Although this questionnaire survey is not an experimental design, some analyses of covariance were conducted to eliminate the influence of intervening variables.

Throughout the evaluation process a set of statistical criteria was applied to all calculations. These criteria are:

- Correlations are only regarded as substantial when they exceed the 0.5 mark. Correlations between 0.1 and 0.5 are regarded as slight connexion. Beyond the mark of 0.7 the correlation is high.

- In the section on the results only the significant results will be described in detail. For further details on non-significant differences the reader should refer to the technical supplement to this report (available upon request).

- ANOVAs with cell numbers below thirty were carefully interpreted. Representativeness of results can no longer be assumed. However, the results may still provide hints for further analysis. Cell numbers below eight were considered not acceptable, and no further analysis was conducted.

- For the same reasons than for the ANOVA interpretation Chi^2-tests with cell numbers below five were not interpreted.

Section 3, 'Results', will describe the findings and will provide illustrating figures. The tables with the statistical details of the calculations can be found in the Appendix. This approach was chosen to keep the section on the results as clear and understandable as possible.

2.5.5 Key elements and open issues

The purpose of Section 4 is to identify the key elements of ageing in ATM. The results of the data evaluation are a collection of more or less isolated findings. These findings are tiles in the big mosaic of ageing and have to be placed in a broader context. To achieve this bigger picture, the outcome of the data evaluation and the findings from a literature review will be applied to a list of controller's cognitive skills. The impact of ageing and experience on these cognitive skills is determined by assessing the changes both in the positive and negative directions. The resulting judgement is either a development of the skill to the positive or negative, or it remains neutral with regard to ageing. The skills which will change to the positive or negative are regarded as the key elements of ageing in ATM.

In Section 5 possible scenarios on how to address ageing in ATM will be outlined. Apart from the introduction, this section is broken down into four sub-sections, each of which represents a certain level of possible actions. These levels are society, management, work processes and individual. The four levels provide a potential for helpful and supportive activities to tackle the problems caused by ageing and to make good use of the benefits of experience.

3. RESULTS

This section describes the cluster analyses conducted as preparation for the data evaluation. It continues with the results of the evaluation. The results are ordered from a point of view of their contribution to the areas of 'cognitive ageing versus gains due to experience', 'job demand and strain', 'ageing and technological change' and 'context factors'.

3.1 Evaluation Preparation

3.1.1 Cluster analysis

Given the amount of data (133 variables) it was necessary to apply a method for screening the date for relevant interactions. Although the theoretical background of the project provides quite a long list of possible interactions, it is useful to check the empirical data for additional hints.

Furthermore, as the survey is aimed at comparing age groups, the definition of cut-off points for 'young', 'middle-aged' and 'old' age groups was another objective. It would have been possible to define such cut-off points from a theoretical point of view. However, as little is known about ageing and experience in ATC, the empirical approach relying on the available data seemed more appropriate.

Since cluster analysis is a method which meets these requirements it was used for the initial screening process. A cluster analysis groups the elements of a sample according to similarity in their characteristics, measured by the questionnaire.

Due to delays in the return of the questionnaires a split approach to the cluster analysis had to be taken. Only about 360 controllers had returned their questionnaire to DIS/HUM by the official deadline (28th February 2002). However, as many verbal confirmations raised the expectation of a substantial number of additional returns, it was decided to conduct some initial analysis with the preliminary set of data. Relevant parts of the cluster analysis were then repeated with the whole lot of questionnaires (1079 pieces) when available, that is end of May 2002.

In total, six separate cluster analyses were conducted. From these six analyses, four were based on the preliminary set of 360 questionnaires and two used the pool of 1079 questionnaires.

The four initial cluster analyses were necessary because, for each group of variables with the same scale level, a separate analysis had to be carried out. Therefore, one cluster analysis was conducted for binary data, one other for ordinal scaled data, one for interval scaled data, and finally one combined analysis for ordinal and interval scaled data. The results from the four

analyses were merged and interpreted all together in an attempt to get an overall picture. This approach is best practice in case of greater sets of data with different scale levels.

The summary of the four initial analyses resulted in a number of relevant interactions amongst the variables. Identification of the three age groups which would be used as basis for further evaluations could already be done. As the division into three age groups was of essential importance for the remaining evaluation, the two additional cluster analyses based on the complete data set of 1077 questionnaires - two had to be excluded because they did not provide information on the age of the controller - were conducted to seek confirmation of this grouping.

Further details regarding the individual cluster analyses, like number of subjects included, variables used for the analyses, interpretation of sub-clusters, etc., can be found in Technical Appendix D.

As the age of subjects is the variable we are most interested in, the results of the cluster analyses were compared using this criteria. To this end the age means and standard deviation of clusters and sub-clusters within each cluster analysis were calculated. As a next step the clusters were compared with respect to as many criteria as possible. The detailed interpretation of the cluster analyses can be found in Technical Appendix D.

3.1.2 Relevant interactions amongst variables

The first Cluster Analysis (CA 1) used only the binary coded variables[4]. It resulted in three main clusters and, not surprisingly, these clusters reproduce groups with respect to ATC services. This could be expected because the number of binary variables taken into account is rather low, and three out of five variables are concerned with ATC service aspects. Gender seems to have some impact, as one cluster includes seventeen female cases. However, the overall number of females is too small to produce representative results. Obviously, as there are substantial differences in age means of the clusters, age as such is also a highly relevant factor. A table with the age means and standard deviations for the four cluster analyses is provided at the end of Technical Appendix D (Table D1).

The second Cluster Analysis (CA 2) included the scaled coded variables[5]. It resulted in two main clusters which turned out to be extremely difficult to

[4] The binary variables included in CA 1 are: *Gender*, *Worked in ACC, Worked in APP, Worked in TWR, Worked in Oceanic control, Currently working ACC, Currently working APP, Currently working TWR, Currently working Oceanic control, Current position: planning controller, Current position: radar/executive controller, Current position: crew chief, Current position: supervisor,* and *General occurrence of technical change.* The binary coded variables *Kind of technical change* and *Other duties 1 to 8* had to be excluded from the analysis due to too many missing values.

[5] The ordinal variables included in CA 2 are: *Part-time work, Transition training: Prior experience with computers, Transition training: technical problems with simulator, Transition training: personal*

interpret. There were few obvious differences between the clusters. Workload and subjective job demand are possible relevant criteria, especially in Cluster 1. Cluster 2 may reflect an interaction between kind of service, workload and job demand. For further details see Technical Appendix D.

The third Cluster Analysis (CA 3) was based on all variables on interval level[6]. It resulted also in two main clusters. The most obvious difference between them is the amount of experience on the current position. Also the workload and attitude towards ageing appear to have some influence (see also Technical Appendix D).

The fourth Cluster Analysis (CA 4) combined the variables on interval and scaled level[5 & 6]. Due to the variables included, all the subjects necessarily see ageing negative (because they give a start age which is an ordinal variable and therefore included in this analysis) and all of them have other duties (interval variable of time demand for other duties). All the sub-clusters are rather homogenous, except for the age means. Therefore, CA 4 may provide a reasonable basis for defining age groups to be used for further analysis. Also, prior experience in other services may be relevant. Details are available in Technical Appendix D.

involvement in system development, Transition training: computer-based training, Transition training: amount of information, Transition training: more training time, Transition training: flexible training time, Compensating power of experience, Direction of the influence of ageing, Gains due to experience: supervisor, Gains due to experience: unusual situations/ emergencies, Gains due to experience: training instructors, Gains due to experience: planning, Gains due to experience: individual differences, Gains due to experience: no gains, Age and experience: situation knowledge, Age and experience: slowing down, Age and experience: safer working, Age and experience: health problems, Age and experience: higher self-confidence, Age and experience: less capacity, Age and experience: knowing 'tricks', Age and experience: less flexibility, Age and experience: higher efficiency, Age and experience: higher job demand, Age and experience: better workload management, Age and experience: learning is harder, Age and experience: lower self-confidence, Age and experience: routine, Age and experience: multitasking, Age and experience: better anticipation, Age and experience: limited mental picture, Age and experience: letter handling of emergencies, Age and experience: problems in decision-making, Age and experience: better planning, Age and experience: stress coping, Age and experience: better prioritising, Age and experience: memory gets worse, Age and experience: broader context knowledge, Age and experience: sustained attention, Age and experience: recovery after work, Job demand: general, Job demand: peak traffic, Job demand: summer season, Job demand: night shift, Influencing factors: part-time work, Influencing factors: radar position, Influencing factors: high traffic load, and *Influencing factors: motivation.*

[6] The interval variables included in CA 3 are: *Age*, *Work start, Since when working on current position, Average number of validations in a unit, Length of the working week in hours, Hours per week spent on other duties, Retirement age, Preferred retirement age,* and *Onset of ageing.*

Taken together, the four cluster analyses revealed the following variables as possibly very influential:

- kind of ATC service,
- peak number of aircraft per hour,
- prior experience in other services,
- kind of current position,
- experience on current position,
- subjective job demand and
- technological change.

Naturally, these variables are not the only ones which were analysed more closely during the evaluation stage. The cluster analyses served mainly the purpose of avoiding to miss important interactions. In the case of this study the cluster analyses did not reveal totally unexpected things; they are rather a confirmation of the findings of previous research and interviews of controllers.

3.1.3 The three age groups: young, middle-aged and old

It was already mentioned in the section above that CA 4 produced the most obvious age-related clusters. The definition of the age groups is of central importance for the evaluation, and therefore a fifth and a sixth cluster analysis were conducted to seek confirmation of the age groups. CA 5 and CA 6 were both based on the complete database including the 1079 questionnaires. CA 5 used exactly the same set of variables as CA 4. However, this procedure unfortunately resulted in a huge number of excluded cases from the cluster analysis due to missing data. From the initial 1077 questionnaires only 156 included the data necessary for the calculation and could be considered for analysis. This number was deemed too low.

The way out of this problem was to reduce the number of included variables. Step by step, the variables with the highest amount of missing data were excluded to see if this improved the number of valid cases. Finally, a trade off was reached between loss of information due to excluded variables and loss of information due to excluded questionnaires. This procedure resulted in the decision to exclude the following variables: *Onset of ageing*, *Average number of validations in a unit* and *Transition training 1 to 7*.

The resulting number of questionnaires included in the analysis is 340. This is still only one third of the questionnaires, but the number of valid cases could not be further increased satisfactorily.

CA 4, CA 5 and CA 6 resulted all in three main clusters. The age means and standard deviations as well as the minima and maxima of values of the three clusters are summarised, for each cluster analysis, in Table 1 below.

The table shows that the mean age of the first cluster varies around 34 years in the three analyses. Also the standard deviations and the extreme values (23-24 and 53-58) are rather similar. The mean age of Cluster 2 lies around

43 years, the standard deviations are again rather close to each other, but the range of values deviates for the third analysis substantially (21 to 58 years instead of 30-33 to 54 years). The mean age of Cluster 3 fluctuates between fifty and 53 years in the three cluster analyses. The standard deviations are again similar and, compared to the other two clusters, very small. The range of values increases with CA 5 and CA 6. In CA 4 the minimum is with fifty years, the maximum with 59, and in the two later analyses the minimum age is already at 45-46 years.

Overall, the two cluster analyses conducted with the whole set of data can be regarded as a confirmation of the initial CA 4 with the limited data set. Both the means and the standard deviations show a satisfactory similarity. Only the range of ages included in the clusters (minimum and maximum values) displays more deviation between CA 4, CA 5 and CA 6.

Table 1: Summary of the age means, standard deviations and extremes of the three main clusters (CA 4, CA 5 and CA 6)

	CA 4	**CA 5**	**CA 6**
Total number of ATCOs	363	1077*	1077*
Valid number of ATCOs	89	156	340
Number of excluded ATCOs due to missing data	274	921	735
Age mean of Cluster 1	**33,53**	**34,19**	**34,35**
Standard deviation of Cluster 1	7,83	7,39	7,73
Minimum age of Cluster 1	23	24	23
Maximum age of Cluster 1	54	54	58
Age mean of Cluster 2	**43,59**	**42,46**	**43,09**
Standard deviation of Cluster 2	6,27	6,42	6,85
Minimum age of Cluster 2	33	30	21
Maximum age of Cluster 2	54	54	58
Age mean of Cluster 3	**53,43**	**50,50**	**51,16**
Standard deviation of Cluster 3	3,54	2,83	3,16
Minimum age of Cluster 3	50	45	46
Maximum age of Cluster 3	59	58	59

*Two ATCOs out of the total of 1079 had to be excluded because they did not provide information on their age.

So far the three cluster analyses only confirm the existence of three age groups in the raw data, which differ from each other. They do not provide any information yet about where to draw the cut-off lines between the three groups. For this purpose, graphs depicting the frequency functions per cluster were produced (see Figures 4, 5 and 6).

The following three graphs show the percentage of controllers per age for the three clusters together with the overall age distribution for the sample. To make the understanding of the graphs easier the clusters are called 'young', 'middle-aged' and 'old'. The points of intersection between the lines of the three clusters are expected to make easier the identification of the cut-off points for the age groups. If the points of intersection were equal in the three different cluster analyses this could be regarded as a solid indication for the borders of the age groups.

In Figure 4 below the black line marks the age distribution of all 363 controllers included in CA 4. The red line displays the age distribution of the young cluster, the green line represents the middle-aged cluster and the blue line marks the old cluster. This graph shows that the edges of the age groups are not clearly cut. The lines intersect repeatedly, displayed by the grey shadows in the graphs. In addition, the overlap between the three distributions is relatively big. Even under the curve for the old group there are some controllers (represented by the red line) who belong to the 'young' group.

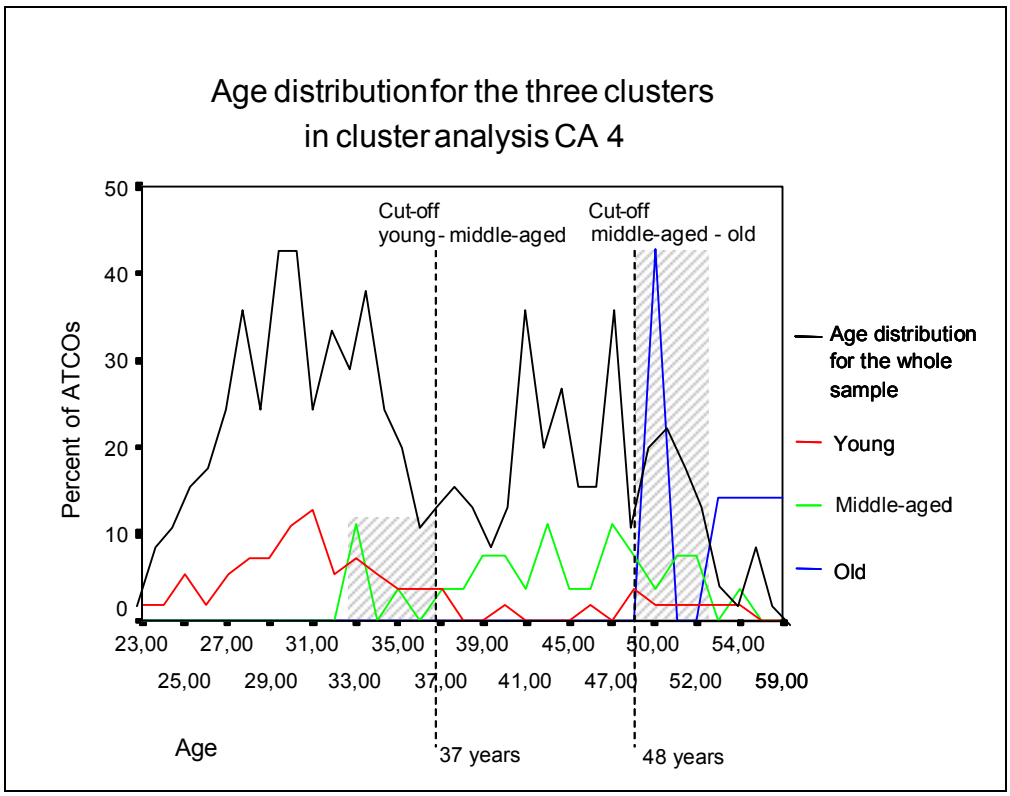

Figure 4: Age distribution of the three clusters in CA 4

The old group has much smaller mean variation. The median of the old cluster is at the age of fifty. Its first intersection with the middle-aged group lays at 48 years but, again, the distributions of the middle-aged and old groups intersect repeatedly. However, the point of intersection at 48 years is the first one between the middle-aged and old clusters. The additional information provided in Figures 5 and 6 may help to come to a conclusion regarding the cut-off points for the age groups.

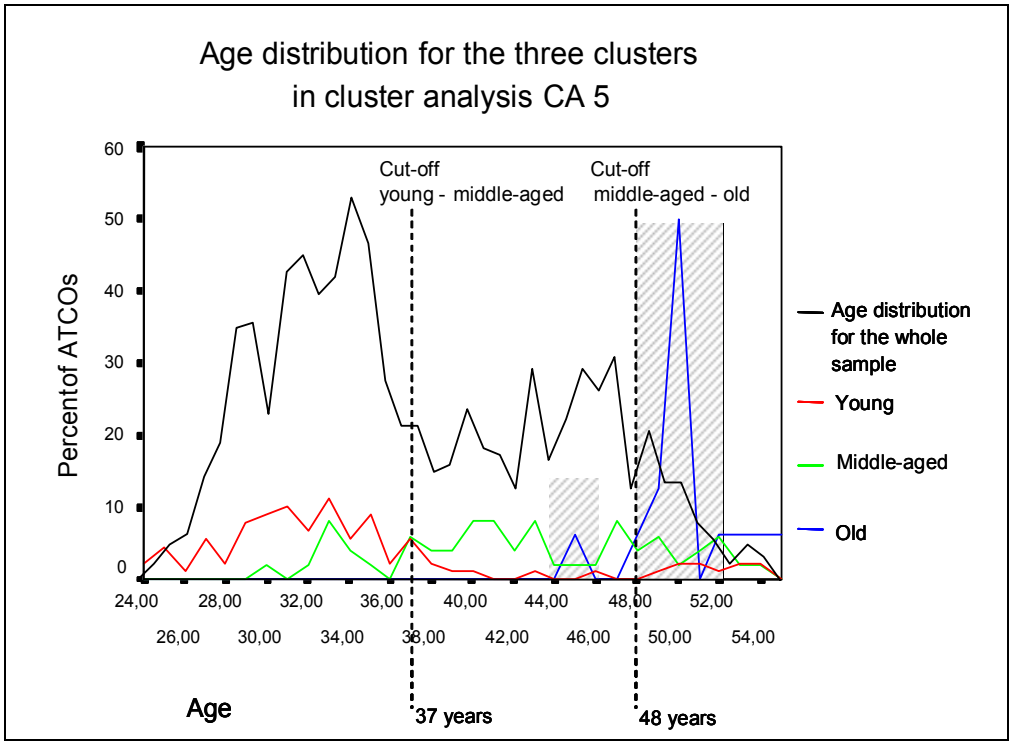

Figure 5: Age distribution of the three clusters in CA 5

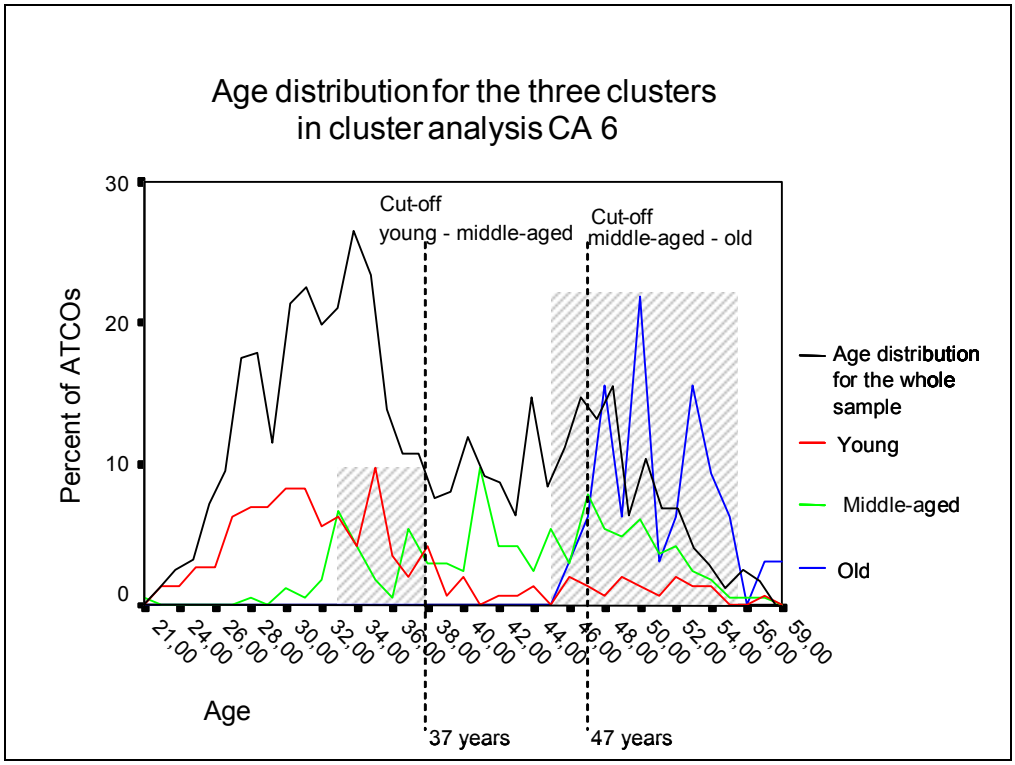

Figure 6: Age distribution of the three clusters in CA 6

Again, in Figure 5 the blue line represents the old cluster, the green line the middle-aged cluster and the red line the young cluster. Here, the intersection between the young and middle-aged clusters is clearly at 37 years, although both distributions have some 'latecomers' up to the maximum age in the sample. The old cluster cuts the distribution of the middle-aged cluster again at the age of 48, although there are a few younger controllers aged 45 in the old cluster. Like before, the median of the old group is at fifty years, and the distributions of the middle-aged and old clusters intersect repeatedly.

Figure 6 above shows the greatest variance in the values for the three distributions. The first point of intersection between the young and middle-aged clusters is at 31 years. However, if the overall age distribution (the black line) of the sample of 1079 is taken into account, this first peak in the middle-aged distribution may only reflect the peak in the overall distribution. The last point of intersection between the young and middle-aged groups is at 37 years.

The middle-aged and old groups intersect first at 44 years and again at 47 years. Although the lines intersect again at higher ages, these ages are not suitable to define the start of the old age group as they lay behind the median at fifty of the old group.

Considering the information from the cluster analyses together with that of the three graphs, the following age groups result in:

- ‘young’: 21 to 36 years,
- ‘middle-aged’: 37 to 47 years,
- ‘old’: 48 to sixty years.

Naturally, the terms ‘young’, ‘middle-aged’ and ‘old’ are relative. The feeling to be either rather old or rather young depends on many factors and circumstances that vary from individual to individual; one can feel old before the age of sixty while the other can still feel young passed this age! The subjective experience of age can hardly be reflected in these rigid groups. Even taking the best possible methodological approach, these age groups and their thresholds could be discussed lengthily. However, for statistical reasons we need cut-off points for the age groups and the approach taken above tries to provide a solid justification for the grouping. Furthermore, the groups identified above are in good agreement with theoretical assumptions from cognitive psychology which support the grouping suggested in this report.

The number of subjects per age groups is displayed in Figure 7 below. As mentioned earlier, since two air traffic controllers did not provide information on their age; the number of subjects taken into account for this statistic is 1077. 568 controllers between 21 and 36 years participated in the survey and form the ‘young age group’. In the ‘middle-aged group’ there are 281 participating ATCOs aged between 37 and 47, while in the ‘old age group’ there are 228 controllers in the age range of 48 to sixty (see also Table D2 in Technical Appendix D).

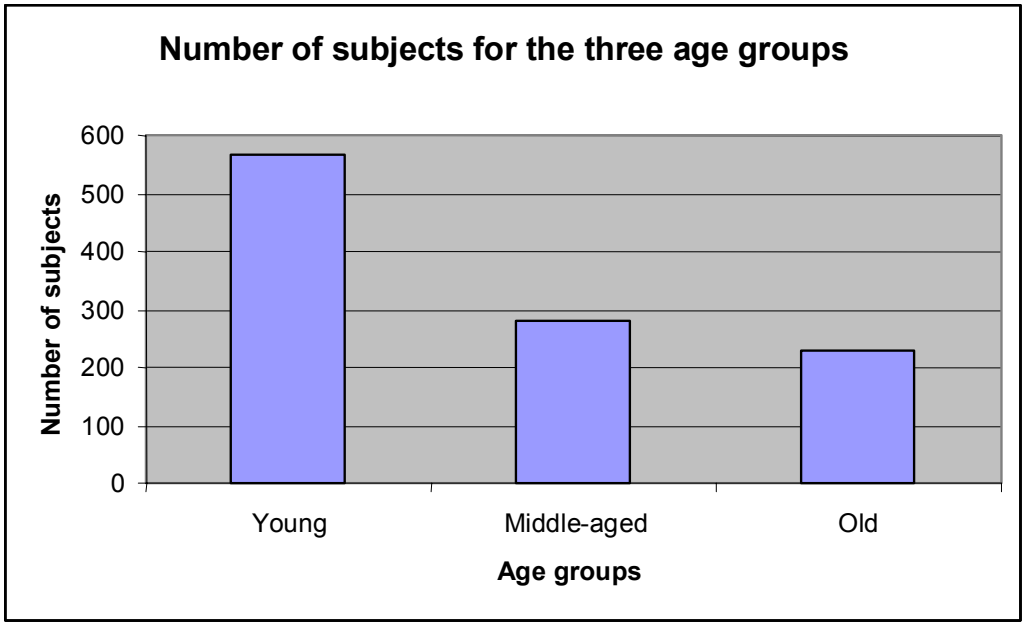

Figure 7: Number of subjects per age group

The mean ages per age group are 30,90 years for the young group, 42,07 years for the middle-aged group and 51,44 years for the old group (see also

Table D3 in Technical Appendix D). The overall mean age for the 1077 subjects is 38,17 years.

Figure 8 below gives an overview of the age means per group.

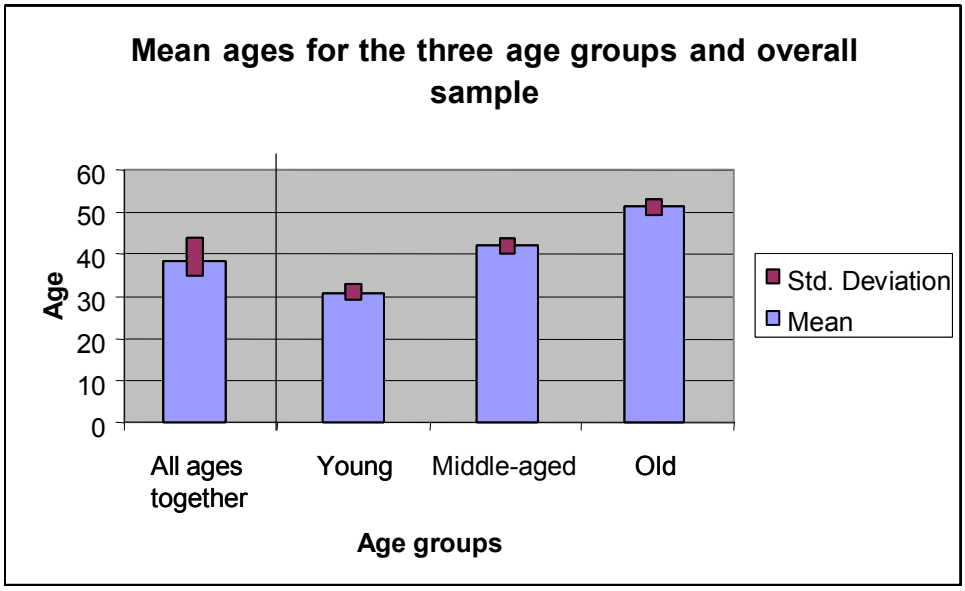

Figure 8: Mean ages and standard deviations for the three age groups and the overall sample

These three groups provide the basis for the statistical evaluations presented in the following sections.

3.2 Context Factors

3.2.1 Introduction

The description of the evaluation results starts with providing information on a number of 'context factors'. These factors are aspects of the ATC environment that are likely to have an influence on the issues of age and experience in ATM. The reason why they are presented at the beginning is that they come back in again under each sub-heading. Naturally, the context factors are of varying importance for the areas of 'cognitive ageing versus gains due to experience', 'job demand and strain' and 'ageing and technological change'. However, they provide the context for the processes this survey is interested in. They are of overall importance for the further analysis.

Although it is not possible to cover all aspects of the ATC environment likely to have an influence (for example, the social or safety culture of an ATC organisation is very hard to capture in a questionnaire survey without

expanding it to five more pages), the most important factors are tackled within the survey.

The following factors were taken into account:

- kind of ATC service (ACC, APP, TWR, Oceanic);
- time spent on tasks/duties other than operational;
- number of validations/ratings;
- prior experience in other services;
- part-time work;
- current function (radar/executive controller, planning/coordinating controller, crew chief, supervisor);
- overall job experience;
- experience on current position;
- the subjective perception of *other influencing factors*.

Each of the above-listed factors is addressed separately in the course of this section. More detailed reasoning on the importance of the factors is provided at the beginning of the sub-sections.

Some of the context factors may interact not only with age, experience, job demand or technological change, but also with other context factors (e.g. 'prior experience in other services' with 'experience on current position'). These interactions are analysed more closely in Section 3.2.10.

3.2.2 Kind of ATC service

3.2.2.1 Background

Obviously, the work varies substantially from ATC service to ATC service. If it did not, a different licence would not be required for each service. The discrepancies start with the training requirements and concern almost all aspects of operational work. Possibly, these differences in the requirements may have consequences for the issues related to age and experience. According to a study conducted by Vogt and Kastner (2001) the ATC services diverge regarding job demand and stress/strain. Therefore, a reasonable assumption would be that ageing may be felt more strongly in a highly demanding service than in a less demanding one. However, the situation is more complex. Many controllers do not work in only one service. They have combined licences, for example for Approach and Tower control. These combinations of services have to be taken into account. The issue of job demand and kind of service will also be addressed in Section 3.4.4.

At this point the evaluation is focused purely on the interaction of age and kind of ATC service.

3.2.2.2 Results

The participating controllers were asked in what kind of ATC service they worked (see also questionnaire Section 1.6 in the Appendix to this report). The questionnaire offered the choice between TWR (Tower), APP (Approach), ACC (Area Control Centre) and Oceanic. Multiple answers were allowed. For example, ticking both APP and TWR was accepted. Table 2 below provides the number of controllers per service and per combination of services. For all the categories the average age was calculated, except for category 'TWR & Oceanic' including only one subject. Table 2 provides the data on the mean ages (see also Table E1 in Technical Appendix E).

Table 2: Mean age per ATC service and per service combination

ATC service	N	Mean	Standard deviation	Minimum	Maximum
TWR	195	36,64	9,134	22	60
APP	94	39,85	9,004	24	57
APP & TWR	230	38,38	9,104	21	59
ACC	418	37,92	8,412	22	58
ACC & TWR	5	42,00	10,173	25	52
ACC & APP	48	36,90	10,058	25	58
ACC, APP & TWR	29	41,31	7,036	30	54
Oceanic	30	41,13	10,673	22	59
Oceanic & ACC	15	41,13	7,170	32	53
Oceanic & TWR	1	34,00	-	-	-
Total	**1065**	**38,16**	**8,910**	**21**	**60**

The first aspect requiring a comment is the highly unequal number of controllers per service respectively service combinations. The most frequent combination is APP and TWR with 230 controllers in our survey. All the other combinations are far less frequent, ranging from 48 controllers in APP and ACC to only one controller doing Oceanic and TWR. The very low number of controllers in some of the service combinations questions the reliability of the statistical evaluation.

In our sample tower controllers (36,64 years) have the lowest average age, followed by ACC & APP (36,90 years), then ACC (37,92 years), APP & TWR (38,38 years), APP (39,85 years), Oceanic (41,13 years), ACC & Oceanic (41,13 years), ACC & APP & TWR (41,31 years), and finally ACC & TWR

(42,00 years) with the highest mean age. This ranking of the mean ages is also displayed in Figure 9 below.

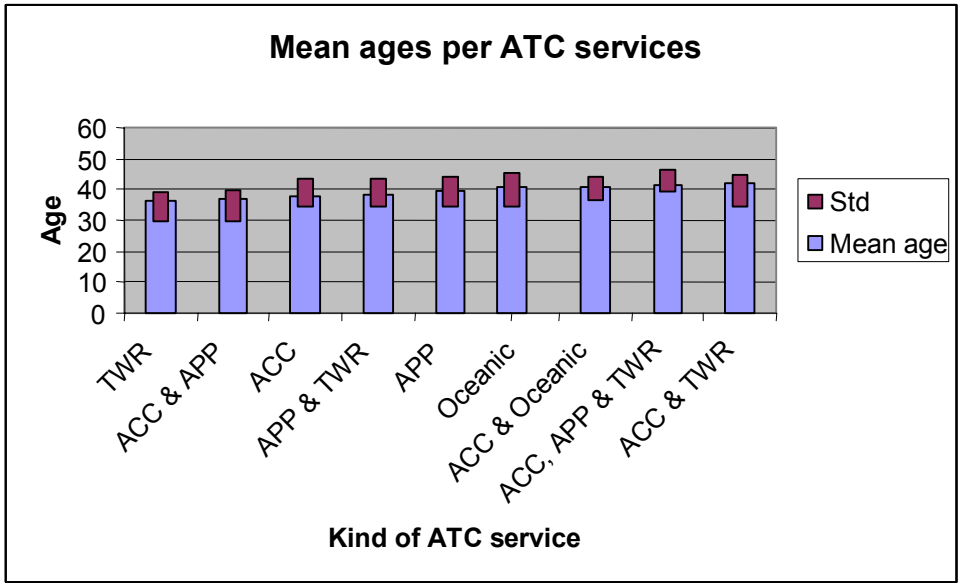

Figure 9: Mean age and standard deviation per ATC service

Interpreting these differences is a difficult task. A statistical test for significance is possible, but, because of the large differences in the group sizes and the very low numbers in some groups, the results should be interpreted with great care. The interpretation is even more difficult because of the categories overlapping. For these reasons the differences in mean ages for the nine categories are not discussed in detail (statistical results can be found in Table F2 in Technical Appendix F).

There may be many reasons behind the variety of mean ages. For example, the low mean age for tower controllers could be related to the fact that in many countries ATCOs start their career, that means they start their training, in tower control. Another interpretation would be the higher job demand in TWR control found by the Vogt and Kastner Analysis (2001), which may cause controllers to move out of this type of ATC service with increasing age. Other reasons could be deviations in the recruitment strategies or simply coincidental fluctuations in the age due to low-case numbers.

Figure 10 displays the percentage of young, middle-aged and old controllers per ATC service. Not only the mean age, but also the age distribution changes with the service. However, the figure shows how strongly the distribution depends on the number of controllers per group. The services TWR, APP, APP & TWR and ACC had the highest numbers of controllers and these services show a very similar age distribution. About 50% of the controllers are between 21 and 36 years, approximately 25 to 30% are in the 37-47 age group, and about 20 to 25% are between 48 and sixty years. For the exact figures see Table E4 in Technical Appendix E.

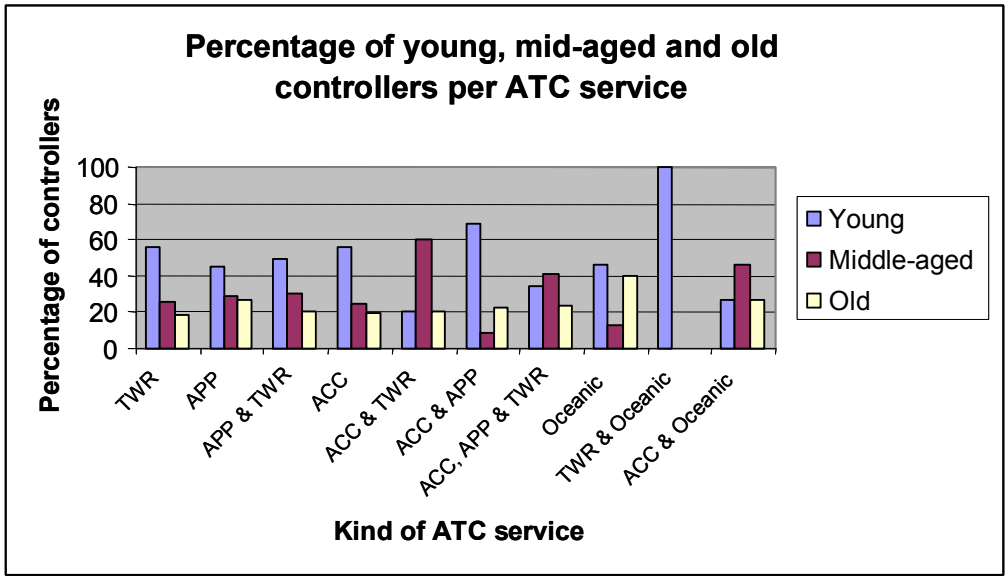

Figure 10: Percentage of young, middle-aged and old controllers per ATC service

For all the other service combinations rather unusual age distributions are recognisable. The most extreme example is definitely TWR & Oceanic control. This is due to the fact that only one controller in our sample does this specific combination of services and, by coincidence, this controller is only 34 years old. This example may have shown that interpreting the results for the groups with very low numbers is not sensible.

It is possible to collapse the small groups of combined services and produce statistically significant age differences this way (see Tables E5 to E7 in Technical Appendix E). However, these results do not contribute any longer to the question whether different services as such have an impact on the age distribution of controllers. Taking also into account the broad possibilities of interpretation of the age differences in ATC services, this question will, for the time being, remain unanswered.

3.2.3 Time spent on tasks other than operational

3.2.3.1 Background

The amount of time and effort spent on tasks other than operational is of high importance in researching ageing impacts. The more time a controller spends on other tasks the greater becomes his or her lack of practice on the operational position. This phenomenon not only concerns older controllers but also young controllers, who take longer breaks off-duty (e.g. maternity leave), and report such a lack of practice. Having a longer holiday is enough to make controllers feel a bit 'rusty' when back on duty, and that is why many of them avoid to take a 'hot seat' right after a longer absence from operational work.

Two aspects of non-operational tasks are interesting with regard to ageing:

- Firstly, one can assume that the three age groups of controllers differ as to the other tasks they may execute. For example, it is reasonable to assume that, with increased age, a controller is more likely to carry out supervisory tasks.

- Secondly, the age groups may vary as to the amount of time they spend on other tasks. It is assumed that older controllers spend more time on non-operational tasks. The following section on results is split according to these two questions.

In Section 1.16 of the questionnaire (see the Appendix to this report) we asked the controllers whether they had other duties in addition to their operational work on the position. The question was 'During your working week, do you have responsibilities other than your operational duty?' Eight alternatives were proposed to them. More than one answer was possible. The suggested 'other duties' were *Instructor on-the-job training; Instructor institutional, simulator or other training; Involved in training projects (e.g. exercise design, transition training); Supervisor/Watch Manager; Other managerial/administrative tasks; Performance assessment/evaluation; Selection of personnel* and *Incident investigation.*

Two additional open questions allowed to complete the list with specific other duties or tasks. One of the open questions addressed involvement in technical projects, the other one was about other projects in general ('Are you involved in technical projects? If yes, please specify the projects' and 'Are you involved in other projects? If yes, please specify the projects').

Finally, the controllers were asked to provide information on the time per week they spent on these other duties: 'How many hours per week do you spend on the above tasks?' (see Section 1.17 in the Appendix).

3.2.3.2 Results

Frequency of kinds of other duty

Table 3a provides the information on the frequency of the other duties. 397 controllers are instructors for on-the-job training, 176 are instructors for institutional, simulator or other training, 115 are involved in training projects, 236 are supervisors or watch managers, 179 have other managerial or administrative tasks, 95 do performance assessment or evaluation, 34 are involved in selection of personnel, and 49 are incident investigators. Table 4 also indicates the frequency of other duties for the three age groups. Remarkable is the high number of young controllers in the training categories and older controllers in the five other categories (supervisor, managerial tasks, performance assessment, selection and incident investigation).

Table 3a: Frequency of eight other duties for the three age groups and the overall sample

Kind of other duty	Frequency young	Frequency middle-aged	Frequency old	Total
Instructor on-the-job training	152	137	108	397
Instructor institutional, simulator or other training	82	53	41	176
Involved in training projects (e.g. exercise design, transition training)	60	33	22	115
Supervisor/watch manager	53	77	106	236
Other managerial/ administrative tasks	61	62	56	179
Performance assessment/evaluation	23	30	42	95
Selection of personnel	6	15	13	34
Incident investigation	11	18	20	49
Total	**448**	**425**	**408**	**1281**

Note: The number 1281 exceeds the total number of subjects (1079) because more than one answer per subject was possible.

Figure 11 below displays the distribution over the various duties in absolute numbers of controllers in the three age groups. The above-described trend in the distribution of the age groups over the different duties is visible in this graph.

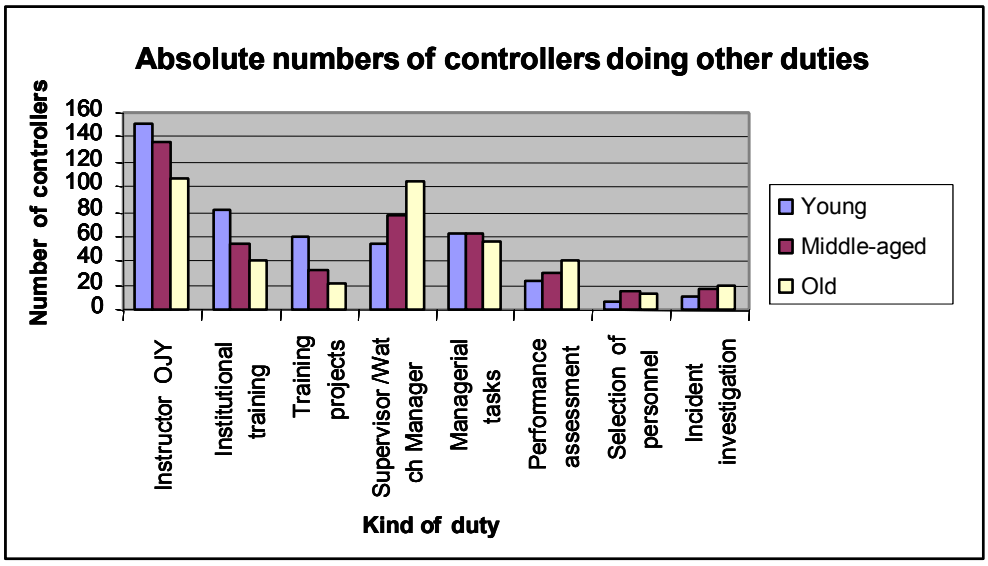

Figure 11: Absolute numbers of controllers performing other duties for the three age groups and the total sample

The two open questions were also evaluated regarding the frequency of controllers being involved in technical projects or other projects. Table 3b below provides the figures for the three age groups and the overall sample.

Table 3b: Frequency of controllers participating in technical projects and other projects

Type of age group	Participation in other technical projects	Participation in other projects
Young	62	63
Middle-aged	13	18
Old	18	19
Total	**93**	**100**

The detailed list of projects in which the controllers of this sample are participating is presented in Tables E86 and E87 in Technical Appendix E.

Table 3c provides the percentage of controllers performing other duties. The sample of 1079 controllers is the baseline and represents 100%.

Table 3c: Percentage of controllers performing other duties

Kind of other duty	Percentage young	Percentage middle-aged	Percentage old	Percentage three groups
Instructor on-the-job training	14,09	12,70	10,01	36,80
Instructor institutional, simulator or other training	7,60	4,91	3,80	16,31
Involved in training projects (e.g. exercise design, transition training)	5,56	3,06	2,04	10,66
Supervisor/Watch Manager	4,91	7,14	9,82	21,87
Other managerial/ administrative tasks	5,65	5,75	5,19	16,59
Performance assessment/evaluation	2,13	2,78	3,89	8,80
Selection of personnel	0,56	1,39	1,20	3,15
Incident investigation	1,02	1,67	1,85	4,54

To highlight the differences between the three age groups Figure 12 shows the percentage of young, middle-aged and old controllers per kind of other duty.

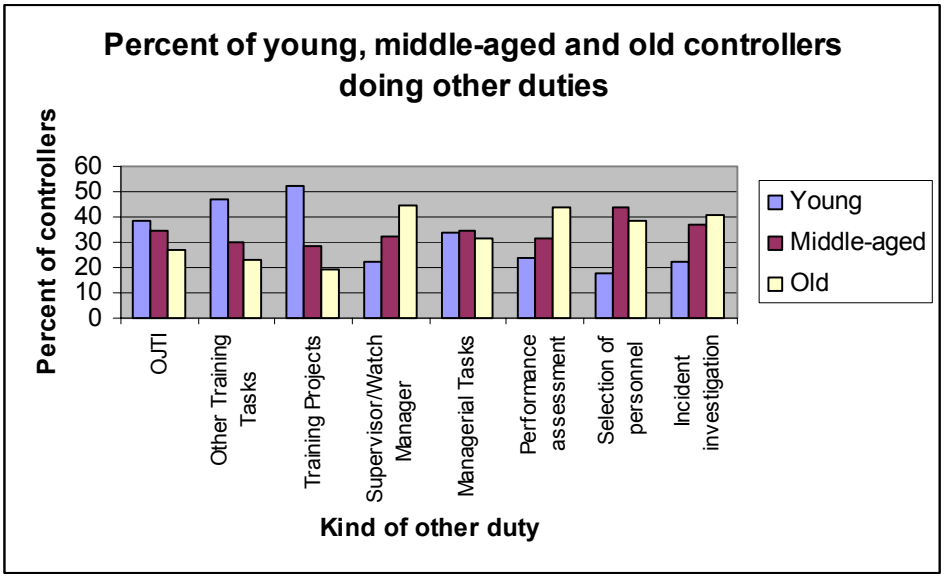

Figure 12: Relative numbers (percentage) of controllers performing other duties in the three age groups and the total sample

The young age group has a rather high number of training tasks whereas the middle-aged and old age groups have higher frequencies in supervisory tasks, managerial tasks, performance assessment, selection of personnel and incident investigation. However, the high number of young controllers being involved in training tasks is not surprising. The 'young' group includes controllers aged from 21 to 36, and a controller in his or her mid-thirties is very well able and sufficiently experienced to act as trainer.

The significance of the above-described trends was tested with Chi^2-Tests for each kind of duty (see also Tables E9 to E24 in Technical Appendix E). The following significant deviations of the observed frequencies from the theoretically expected frequencies[7] could be identified:

- Instructor on-the-job training: Significantly more young and middle-aged controllers, and less old controllers than expected are instructors for on-the-job training (see also Tables E9 and E10 in Technical Appendix E).
- Instructor institutional, simulator or other training: No significant deviation of the observed frequencies from the expected frequencies could be identified (see also Tables E11 and E12 in Technical Appendix E).
- Involved in training projects (e.g. exercise design, transition training): No significant deviation of the observed frequencies from the expected frequencies could be identified (see also Tables E13 and E14 in Technical Appendix E).

[7] The theoretically expected distribution assumes an equal distribution of cases over the available categories.

- Supervisor/Watch Manager: Significantly more middle-aged controllers, many more old controllers, and less young controllers than expected are supervisors or watch managers (see also Tables E15 and E16 in Technical Appendix E).

- Other managerial/administrative tasks: More middle-aged and old controllers, and less young controllers than expected perform other managerial tasks (see also Tables E17 and E18 in Technical Appendix E).

- Performance assessment/evaluation: More middle-aged and old controllers, and less young controllers than expected are involved in performance assessment or evaluation (see also Tables E19 and E20 in Technical Appendix E).

- Selection of personnel: More middle-aged and old controllers, and less young controllers than expected are involved in selection of personnel (see also Tables E21 and E22 in Technical Appendix E).

- Incident investigation: More middle-aged and old controllers, and less young controllers than expected are incident investigators (see also Tables E23 and E24 in Technical Appendix E).

Linking these results back to the hypothesis formulated at the beginning of this sub-section, it has to be concluded that indeed the age groups differ with regard to the kinds of other duty they execute. Young controllers are more involved in training-related tasks (especially On-the-Job Training [OJT]), whereas middle-aged and old controllers show a higher involvement in supervisory and managerial/administrative tasks, and in selection, performance assessment and incident investigation.

Time spent on other duties

The average time the controllers in our sample spend on the other tasks described in the previous sub-section is 13,55 hours per week. Again, this average time varies according to the age of the subjects (see also Table E25 in Technical Appendix E). On average the young group spends 11,55 hours per week on other duties, the middle-aged group 14,27 hours per week and the old group 15,86 hours per week. Figure 13 shows these average times and standard deviations for the three age groups and the whole sample.

An Analysis Of Variance (ANOVA) for age groups and time spent on other duties was calculated. It revealed a highly significant (α=1%) difference between the mean times of the three age groups (see Table E26 in Technical Appendix E).

The supplementary *post hoc* Tukey HSD tests found a highly significant difference between the mean time of the old group and that of the young group. The old group spends significantly more time per week on other

duties than the young group does (for details see Table E27 in Technical Appendix E).

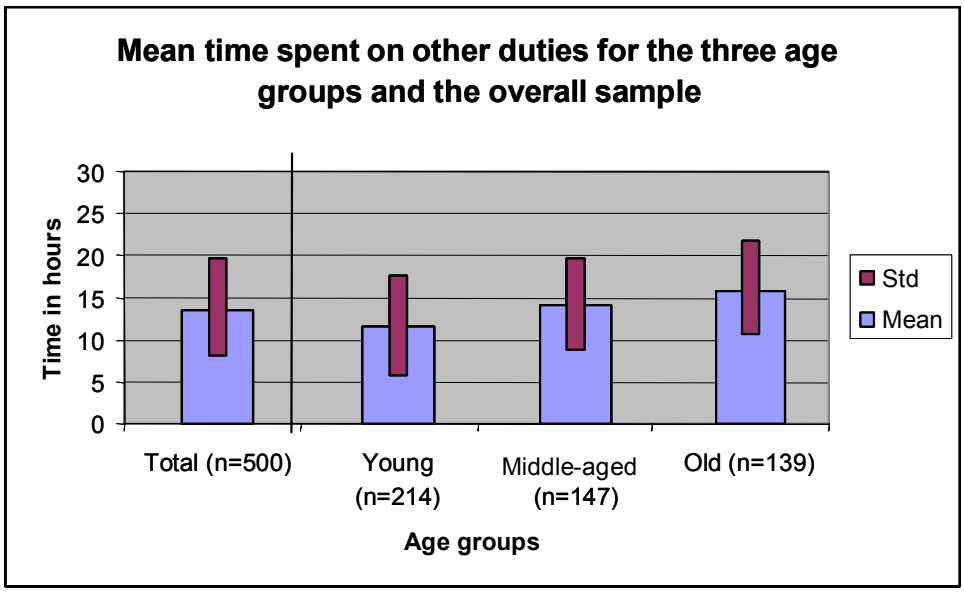

Figure 13: Average time in hours spent on duties other than operational for the three age groups and the overall sample

Again, this result confirms the hypothesis formulated in the introduction. Old controllers indeed spend more time than young controllers on non-operational tasks and duties. There may be many reasons for this:

- individual preferences may be influential;
- it may be that older controllers are better suited for a number of other tasks (e.g. performance assessment, managerial or supervisory tasks), thanks to their broad experience;
- another factor may also be the tendency of some older controllers to move out from operational positions because they admit their personal limits.

3.2.4 Number of validations

3.2.4.1 Background

During the interview study on ageing conducted by EUROCONTROL in 2001 some controllers stated that with increased age it became more likely to drop validations for the very busy sectors. This might be the case only for ATC units with an extremely high traffic load. However, as handing in a validation for a sector is an important decision for the operational career of a controller it is worth exploring it deeper within this project.

Referring to the statement of the controllers in the interview study, it should turn out in the statistical evaluation of the questionnaire data that older controllers on average hold less validations for sectors than young controllers.

3.2.4.2 Results

The questionnaire asked two different questions about this issue (see also the Appendix, Sections 1.9 and 1.10 of the questionnaire). The first question enquired the average number of validations per controller ('How many validations (average) do controllers have at your unit?'). In the second question the controllers had to name all the working positions for which they personally had validations.

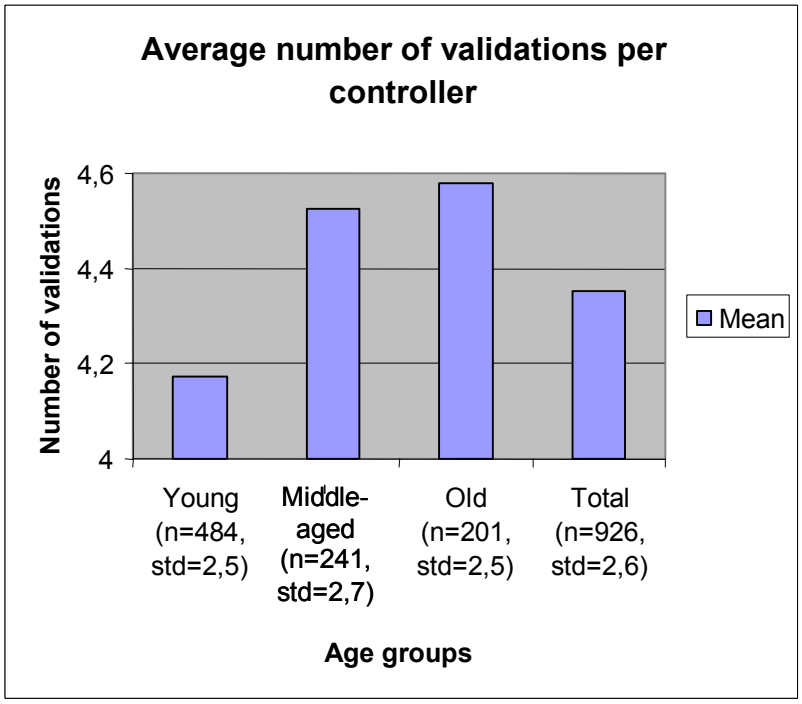

Figure 14: Average number of actual validations for the three age groups and the overall sample

The average number of validations in the units is 3,58 (std=2,52), the average number of validations per controller is 4,35 (std=2,57; see also Table E28 in Technical Appendix E). The following statements use the actual number of validations per controller as reference. The three age groups show a slight difference in their mean number of validations (see Figure 14 above). The young group has on average 4,17 validations, the middle-aged group 4,52 and the old group 4,57 (see also Table E29 in Technical Appendix E).

An ANOVA for age groups and the number of actual validations did not reveal significant differences between the mean number of validations of each age group (see Tables E30 and E31 in Technical Appendix E).

Therefore, the initial hypothesis that older controllers hold less validations than young ones has to be rejected. In fact, the data shows the contrary, even if the trend is not significant as older controllers have only slightly more validations than young ATCOs.

3.2.5 Prior experience in other services

3.2.5.1 Background

Prior experience in ATC services other than the one in which a controller currently works is a relevant aspect of overall job experience.

It potentially contributes to the quality of interactions between colleagues. Just think of a handover to an adjacent sector, from ACC to APP or from APP to TWR. Moreover, making a transition from one unit to the other might support the individual in other transition situations, like technological system upgrades or substantial airspace restructuring, etc. Of interest for this survey is the question whether prior experience in other ATC services helps to make the transition to new technological equipment. This matter will be debated in Section 3.5, 'Ageing and Technological Change'.

With regard to ageing no explicit hypothesis is formulated. Various or even contradictory scenarios are possible. On the one hand the change of services might help older controllers to stay flexible and adaptable. On the other hand, the repeated change of services shortens the time per service to gather specific knowledge for a certain ATC environment. It might counteract the development of routines and the building up of the specific kind of expertise, so relevant to bridge the gap caused by declined due to ageing. For the time being it is only checked in this section whether there is, at all, a relation between age of controllers and prior experience in other ATC services.

3.2.5.2 Results

The questionnaire asked both where the controllers worked, and where, for how long and in what ATC services they used to work (see questionnaire Sections 1.5 and 1.6 in the Appendix). The information on the current workplace was contrasted to the information on other ATC services in which controllers used to work. From this comparison the experience duration in ATC services other than the current one was concluded.

721 controllers in our sample do not have any prior experience in an ATC service other than the one they currently work in. For 22 cases the information is missing. 336 have prior experience in other ATC services. The following statistical evaluation is therefore based on these 336 cases.

Figure 15 shows the average years of prior experience in other ATC services. The total group has a mean time of experience in other services of 6,61 years. The young group has a mean time of 3,22 years, the middle-

aged group of 7,19 years and the old group of 10,52 years (see also Table E32 in Technical Appendix E).

Pearson's correlation between age and prior experience in other services achieves a value of r=.498. This value can be interpreted as a correlation of medium strength between the two variables (see also Table E33 in Technical Appendix E).

A comparison of means with ANOVA also revealed a highly significant (α=1%) difference and the *post hoc* Tukey HSD tests confirmed a highly significant difference between the three age groups. The young group has a significantly shorter prior experience than the middle-aged and old groups. The middle-aged group has a significantly longer prior experience than the young group and a significantly shorter mean prior experience than the old group. The old group has a significantly longer prior experience than the middle-aged and young groups (see also Tables E34 and E35 in Technical Appendix E).

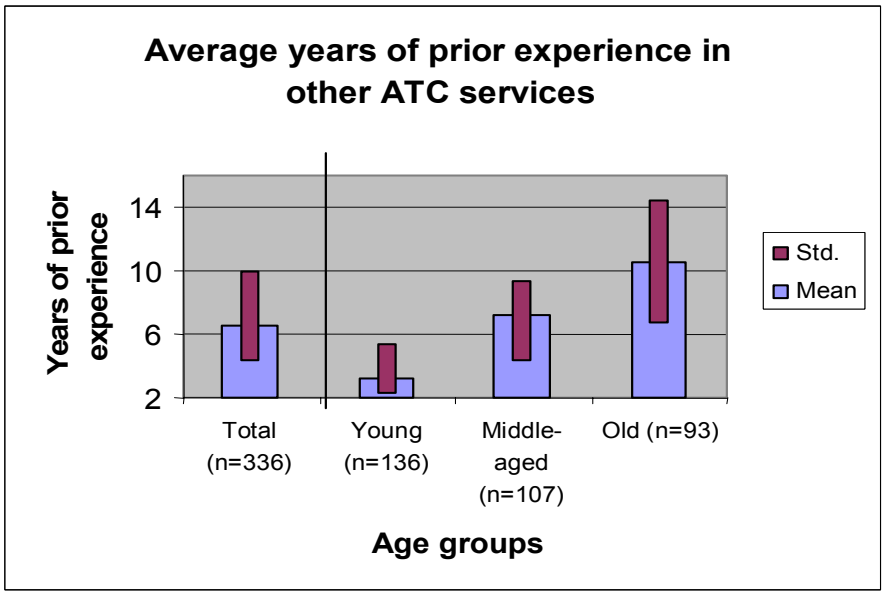

Figure 15: Average years of prior experience in other ATC services for the three age groups and the total sample

The data clearly shows a link between the controllers' age and their prior experience in other ATC services. This result is not surprising, as with increased age the likelihood of having worked in other ATC environments almost naturally increases too.

3.2.6 Part-time work

3.2.6.1 Background

There is a simple reason why part-time work is of interest for ageing. The less time is actually spent on the working position the greater becomes the lack of practice in this position. As stated earlier in this report, young controllers suffer from decreased 'fluency' in their skills when they are away from their position for too long. For older controllers this effect is possibly compounded by the negative development due to ageing.

This section first investigates the relation between age and part-time work. No assumption is made regarding this relation.

3.2.6.2 Results

The questionnaire asked about whether the controllers work fulltime or part-time. The question provided a choice between four categories: fulltime, 99-80%, 79-50% or less than 50% (see also questionnaire Section 1.15 in the Appendix to this document).

827 of the controllers work fulltime, 81 work between 99 and 80%, 135 work between 79 and 50%, and only 25 work less than 50%. In total, 241 controllers do part-time work (see also Tables E36 and E37 in Technical Appendix E). For eleven cases the data is missing. The 241 controllers doing part-time work represent 23% of the ATCO sample of this survey (see Figure 16 below).

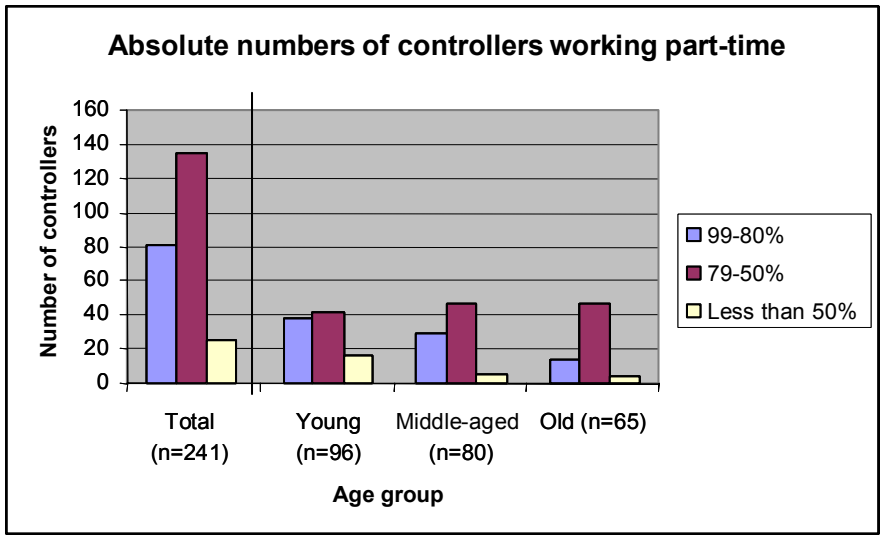

Figure 16: Absolute numbers of controllers working part-time for the three age groups and the overall sample

A Chi^2-test checked the observed frequency of part-time work for the three age groups for significant differences from the expected frequencies. The Chi^2-test revealed highly significant (α=1%) deviations of the observed distributions from the expected distributions (see also Table E38 in Technical Appendix E).

Table 4 below provides a summary of the interpretation of the results from the Chi^2-test.

The young age group works more part-time than expected in the categories of 99 to 80% and less than 50%, and the young group does less part-time work than expected in the 79-50% category. At the same time the old age group works more part-time than expected in the 79-50% category, and less than expected in the category from 99 to 80%. The middle-aged group shows only slight deviations from the expected frequencies.

The high percentage of young controllers working less than 50% could be explained with the higher demand of family duties on these controllers.

The high amount of 79-50% part-time work among the old controllers cannot be explained so easily. Both rather young 'old' controllers (i.e. of 47 or 48 years of age) and older controllers (i.e. between 53 and 55 years) do this kind of part-time work. Possibly this result reflects regulations concerning concepts of 'part-time retirement' in a number of countries.

Table 4: Summary of deviations of observed frequencies from expected frequencies of part-time work for the three age groups

Type of age group	Proportion of part-time work		
	99 to 80%	79 to 50%	Less than 50%
Young group	More than expected (38;32,3)	Less than expected (42;53,8)	More than expected (16;10)
Middle-aged group	Slightly more than expected (29;26,9)	Slightly more than expected (46;44,8)	Less than expected (5;8,3)
Old group	Less than expected (14;21,8)	More than expected (47;36,4)	Less than expected (4;6,7)

Note: The first figure represents the observed frequency, the second figure the expected frequency.

The exact figures on which this summary is based are provided in Table E39 in Technical Appendix E.

In general, these results appear to depend to a high extent on different national or even regional rules and regulations concerning part-time work, or on centre-specific rules and regulations. Both the background provided by society (for example how frequently males work part-time due to family reasons, and how this is accepted) and the influence of trade unions (for example for retirement arrangements) should not be underestimated.

3.2.7 Current function

3.2.7.1 Background

The actual function of a controller at her or his working position is highly relevant for this survey. The questionnaire differentiates between the functions Radar (executive) Controller (RC), Planning (coordinating) Controller (PC), Crew Chief (CC) and Supervisor (SU). These functions require different skills and vary in the kind of demand they place on controllers. For example, the position of a supervisor requires more leadership skills than the radar position. This statement does not neglect the necessity of assertiveness towards pilots on the radar position, but still radar work and supervisor tasks differ in the nature of social skills required. And although supervisors may be faced with emergency situations where they have to take immediate decisions these situations are luckily exceptional. Quick decision-making is rather the day-to-day job of an executive controller.

Taking into account, not strictly, these outlined differences between the functions, a number of hypotheses may be ventured in relation to ageing.

Regarding the supervisor function it can be assumed that older controllers fill this position. The results from Section 3.2.3 already point in this direction.

In the explorative interview study many controllers stated that the negative sides of ageing were more pronounced when working the radar/executive function. Therefore, it is assumed that more young controllers do radar work than their older colleagues do.

Taking into account both that radar work appears to become more demanding with increased age and that increased experience provides advantages in planning tasks, it is assumed that more older controllers work planning positions.

3.2.7.2 Results

Current function in this survey is defined as the actual working position of a controller. The available categories in the questionnaire are Planning (coordinating) Controller (PC), Radar (executive, including executive procedural control) Controller (RC), Crew Chief (CC) and Supervisor (SU). An additional open question allowed to name other functions (see also Section 1.8 in the appended questionnaire). Of course, a controller can have more than one function. For example, the combination of PC and RC is very frequent. Therefore, the evaluation takes all combinations of the four functions into account.

Table 5 below provides the figures for the distribution of the 1079 controllers of this survey over the possible functions and combinations of functions.

The majority of controllers work as RC and PC in combination (451 ATCOs).

The second most frequent function is RC (155 ATCOs) followed by the combination of PC, RC and SU (73 ATCOs).

Also, a rather frequent combination is all four functions together (PC + RC + CC + SU) with 65 cases.

Rather rare are combinations like PC, CC and SU with only two cases, PC and CC with one case, or CC and SU with three cases. For forty cases the data is missing. Table 5 also provides the figures for each of the three age groups individually.

Table 5: Frequencies of functions for the three age groups and the overall sample

Function or combination of functions	Frequency young group	Frequency middle-aged group	Frequency old group	Frequency total
PC	22	22	8	52
RC	101	29	25	155
CC	13	7	7	27
SU	21	3	3	27
PC+RC	222	132	95	451*
PC+CC	0	1	0	1
PC+SU	3	0	4	7
RC+CC	11	0	4	15
RC+SU	21	4	8	33
CC+SU	0	1	2	3
PC+RC+CC	14	4	15	33
PC+RC+SU	40	25	8	73
PC+CC+SU	0	1	1	2
RC+CC+SU	17	2	1	20
PC+RC+CC+SU	42	16	7	65
Other functions	29	22	24	75
Missing	12	12	16	40
Total	**568**	**281**	**228**	**1079**

* As mentioned earlier in this report, two questionnaires had to be excluded from the age groups because they did not include information on the controllers' age. However, this total does not reflect the removal of the two corresponding replies.

The number of functions other than the four alternatives provided by the questionnaire is rather high (75 ATCOs). These 75 other functions are further broken down in Table 6.

Table 6: Kind and frequency of functions, other than the four basic functions, per age group

Other functions				
	Young	**Middle-aged**	**Old**	**Total**
Tower and/or ground controller	8	14	11	33
Tower and approach controller	2	4	9	15
Trainee controller	4	0	0	4
Flight Information Service	14	0	1	15
OJTI/Examiner	0	0	2	2
Others	1	4	1	6
Total	**29**	**22**	**24**	**75**

As detailed in Table 7 one reason for the high number of other functions is the fact that many tower and approach controllers (33 for TWR/GND and fifteen for TWR/APP) did not classify their current function as one of the four proposed alternatives. However, the total number of tower and approach controllers or the combination of the two services in the overall sample is much higher (520 ATCOs). Therefore, we have to assume that most controllers working in a tower unit or in approach control made their choice among the available alternatives to describe their current function.

Figures 17a and 17b give the number of ATCOs per age group in the different functions and combinations of functions. For better legibility the data was spread out over two graphs.

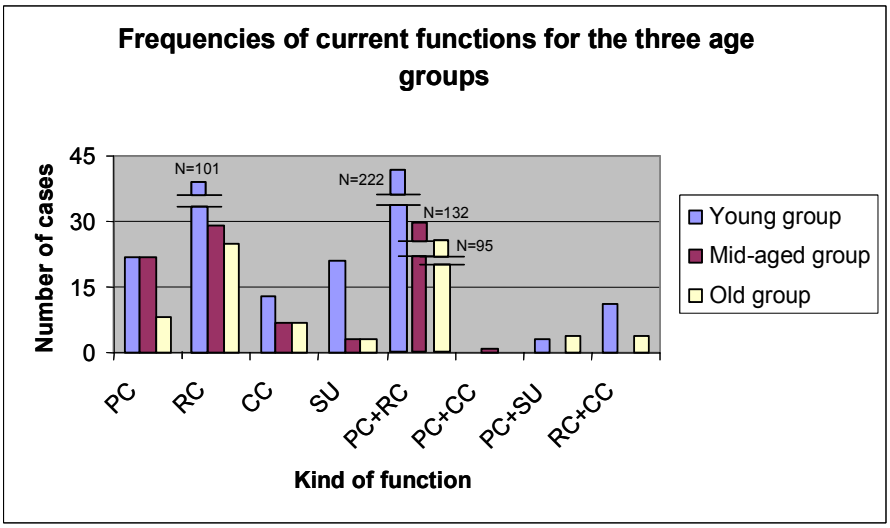

Figure 17a: Absolute numbers of ATCOs in eight ATC functions and combinations of functions for the three age groups

A Chi^2-test was calculated to check whether the observed frequencies per function deviated from the theoretically expected frequencies.

The Chi^2-test revealed a highly significant deviation of the expected frequencies from the observed frequencies (α=1%; see also Table E41 in Technical Appendix E). The cross-tabulation for age groups and kind of functions (see Table E40 in Technical Appendix E) with the observed and expected frequencies provides some interesting insights.

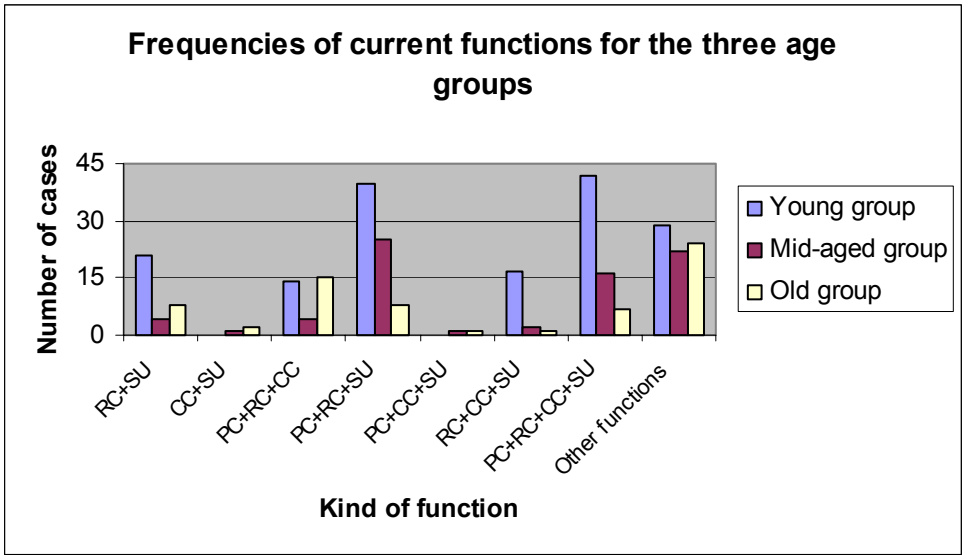

Figure 17b: Absolute numbers of ATCOs in eight ATC functions and combinations of functions for the three age groups

The old group has a higher number of cases for the PC, RC and CC function combination, and for the CC & SU, and PC & SU combinations. Furthermore, this group has a substantially higher number of ATCOs working in other functions. The young group has higher frequencies in the RC and SU functions and have more cases in the RC, CC and SU combination of functions, and in the combination of all four functions (PC + RC + CC + SU). The middle-aged group has more cases as PC and in other functions, and also have more ATCOs in the PC & RC, CC & SU and PC, RC & SU combinations of functions.

To sum up, it appears that older controllers work more in combinations of functions involving supervisory or leadership functions (crew chief or supervisor), and that they tend to be more involved in functions outside the frame of the four 'classic' functions. The young group (not surprisingly) has a higher number of radar controllers and a lower number of planning controllers, but at the same time a surprisingly high number of ATCOs in supervisory tasks, and in combinations of supervisory and radar tasks. The high number of young controllers in supervisory functions may be due to the fact that the highest age in this age group is 36 years. The middle-aged group has a higher number of cases of combinations involving the PC function.

3.2.8 Overall job experience versus experience on current position

3.2.8.1 Background

Not surprisingly, age and experience are two highly confounded variables. The older one gets the more professional experience one can accumulate. This survey tries to tackle this problem by differentiating between the overall job experience of a controller and his or her experience on the current position. The results described below demonstrate that these two aspects of the experience indeed show different patterns.

3.2.8.2 Results

The questionnaire included two questions dealing directly with job experience. The first one addressed overall job experience ('When did you begin to work as an air traffic controller?'), while the second question was 'For how long have you been working in your current position?' (see also Sections 1.4 and 1.7 of appended questionnaire).

Overall job experience

On average the controllers who participated in this survey have an overall job experience of 14,15 years (std=9.20). Comparing the three age groups it can be seen that there are substantial differences between them in the mean experience on the job (see also Table E42 in Technical Appendix E): the young group has 7,19 years of experience (std.=3,71), the middle-aged group 17,58 years (std=5,31) and the old group 27,13 years (std=5,05). Figure 18 below depicts these differences.

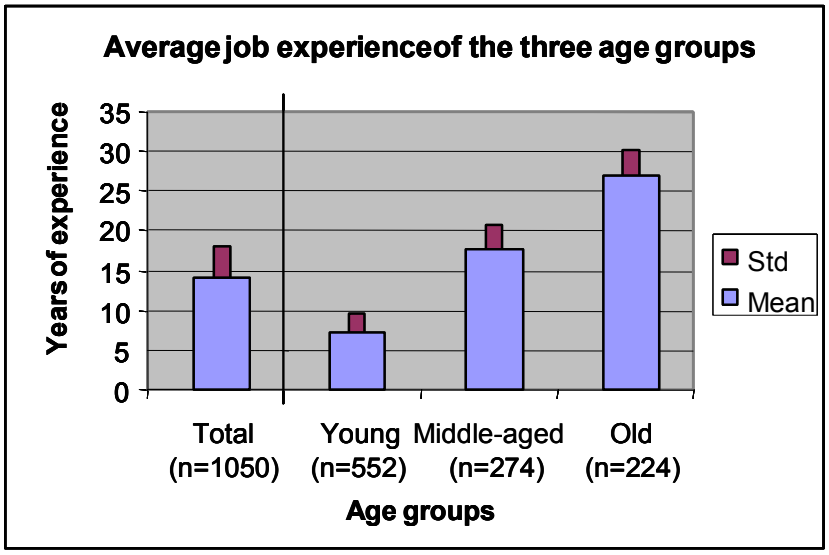

Figure 18: Average job experience of the three age groups and the overall sample

The correlation between the two variables age and years of experience is with r=.927 extremely high and highly significant on the .01 level (see also Table E43 in Technical Appendix E).

The comparison of mean years of experience per age group using ANOVA revealed a highly significant mean difference (α=1%). The *post hoc* Tukey HSD tests confirmed a highly significant difference between the three age groups (see also Tables E44 and E45 in Technical Appendix E). Not surprisingly, with these results we got the confirmation that the difference of about ten years in the mean experience of the three age groups is highly significant.

Up to now the results confirm exactly what one would expect: the older a controller, the higher is his or her overall job experience. The following explanations on experience on the current position will however show that it is necessary to distinguish between different types of experience.

Experience on current position

The actual time spent on the current working position shows a pattern which is different from the overall experience. Even though the correlation between age and time spent on the current working position is, with r=.694, still very high (see also Table E46 in Technical Appendix E), it is remarkably lower than the correlation between age and overall experience (r=.927).

Figure 19 below shows the mean times on current position for the three age groups and the overall sample.

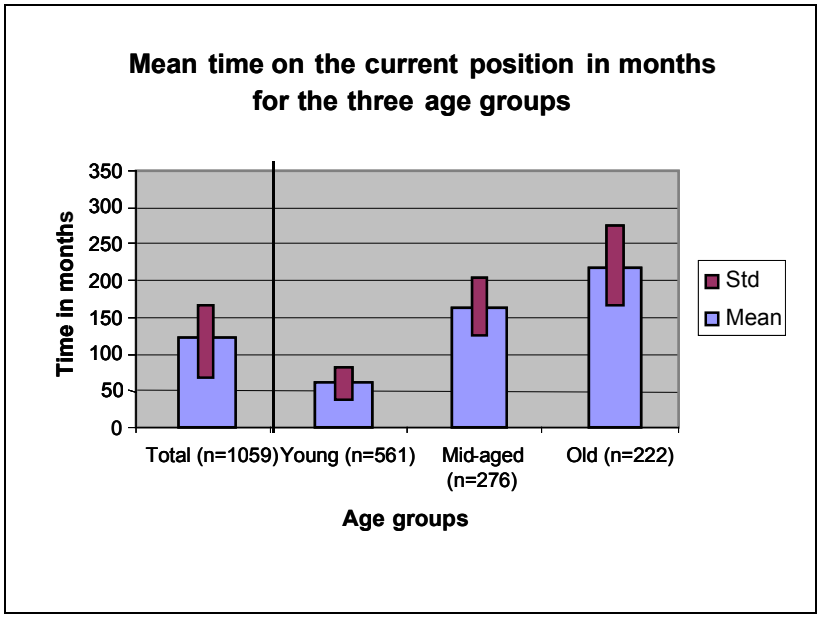

Figure 19: Mean time on the current position in months for the three age groups and the overall sample

The mean time spent on the current position is 120,38 months (std.=96,66 months) for all controllers. Again, the three age groups show substantial differences in their mean time on current position. The young group has a mean time of 61,61 months, the middle-aged group of 160,31 months and the old group of 217,89 months (see also Table E47 in Technical Appendix E).

Just as for the overall experience, the ANOVA comparing the mean time on current position confirmed a highly significant difference between the means of the three age groups. The Tukey HSD tests also resulted in the finding that there were highly significant differences between the three age groups (for details see Tables E48 for the ANOVA and E49 for the Tukey tests in Technical Appendix E).

The scatter plot with the raw data shows an interesting distribution of raw data (see Figure 20 below). In the upper left corner of the graph there is a great number of controllers who are relatively old but have a comparably low time on their current position. The graph of raw data for age and overall job experience does not show such a pattern (see Figure E1 in Technical Appendix E). This distribution raises the question why these controllers have such a low experience on their current position. This is a very interesting question, as the answer might reveal career alternatives to operational work. In addition, it would be worthwhile to find out whether these controllers are 'ageing victims' who left their positions because they could not cope with the demand any longer, or whether they are just people who seek new challenges and have a stronger need for variety in their job.

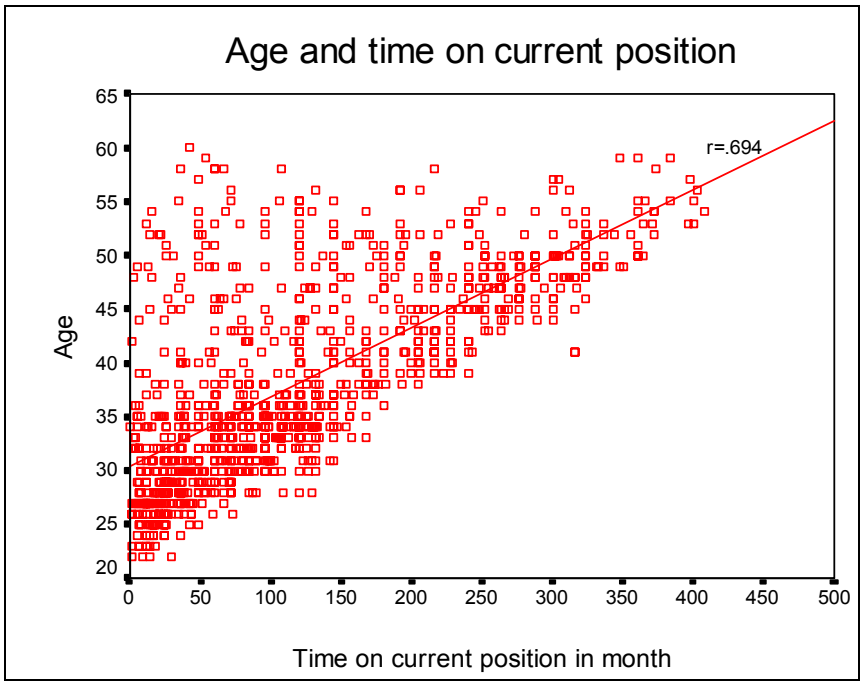

Figure 20: Raw data for age and time on current position in months

To answer this question the concerned cases were identified and further analysed. Only the middle-aged and old age groups were taken into account, because for the young group this effect was not yet visible. The young controllers who have a below average experience on their current position are very similar to those controllers in the sample who have just recently started working as air traffic controllers. From the mean time on current position for the two age groups concerned one standard deviation was subtracted (see Table 7 below). Any value below the mean age minus on standard deviation was regarded as low experience on current position. For the old group this cut-off value was 108,658 months and for the middle-aged group 83,365 months. The values for the young group are included in the table. However, no further analysis was conducted on this group.

Table 7: Mean time on current position in months, standard deviation and cut-off value for the middle-aged and old groups

Type of age group	Mean time on current position in months	Standard deviation	Cut-off value
Young group	62,485	44,734	18
Middle-aged group	161,507	78,142	84
Old group	218,996	110,338	109

The results for the two age groups are treated separately in the following section.

The old group

Of 228 controllers in the old group 177 have an average to high experience on their current position. For six controllers the data is missing. 45 ATCOs have a low experience on their current position, that is below 108 months. When studying these 45 cases closer we can conclude that twelve ATCOs have changed the ATC service within the past few years. For example, they switched from APP and TWR to ACC, or from ACC to Oceanic control, etc. Also controllers who reduced their variety of services are included in this category (e.g. ATCOs formerly working APP and TWR and now focusing on TWR solely). 33 ATCOs have a low experience on their position but did not change the ATC service (see also Table E50 in Technical Appendix E).

A test for identifying the differences in the frequency of other functions, apart from the four suggested in the questionnaire (PC, RC, CC, SU, see Section 3.2.7), did not, when compared to the group with average or high experience, result in significant differences (for the statistical result see Tables E51 and E52 in Technical Appendix E). The reason for the little time spent by the above-mentioned 33 controllers on their current position is not, therefore, a switch of function outside the operational context.

Unfortunately, further analysis regarding differences in the kinds of operational function could not be conducted because the case numbers

became extremely low (see Table E53 in Technical Appendix E). Therefore, it is impossible to say whether the controllers with low experience, for example, are individuals who have only recently started working as supervisors.

From the survey data it is not possible to provide an explanation why these controllers have such relatively low experience on their current position. However, some interesting differences between these ATCOs and those with an experience on their current position ranging from average to high could be identified.

The controllers with a low experience on their current position are on average slightly older than their colleagues with a higher experience. The difference in age is only 1,5 years. However, a T-Test confirmed this as a significant difference in the mean ages of the two groups (see Tables E54 and E55 in Technical Appendix E).

In addition, the group with low experience perceives the direction of the impact of ageing more extreme than the 'high experience' group does. The first group sees ageing either positive or negative, but not so much neutral as the group with more experience. A Chi^2-Test showed that this difference was significant (see Tables E56 and E57 in Technical Appendix E).

Furthermore, the group with low experience on current position rated night shifts as more demanding than the group with more experience (for the significance test see Tables E58 and E59 in Technical Appendix E). They also rated the influence of ageing as more pronounced on the radar position and in high-workload situations (see Tables E60 and E61 in Technical Appendix E).

Other differences between the two groups could not be identified. Further tests were done about number of aircraft per hour in the sector, the perception of the onset of ageing, the compensating power of experience, hours per week spent on tasks other than operational, frequency of other duties, number of validations, occurrence of technological change at the workplace, job demand and influencing factors, but no significant effects other than the ones described above were found.

The middle-aged group

Of the 253 controllers of the middle-aged group, 194 have an average or high experience on their current position, 54 have a low experience on their current position, that is below 84 months, and for five controllers the data is missing. Of the 54 controllers with low experience, thirteen have recently changed the ATC service (for example, within the past three years they have changed from Oceanic control to ACC, or have reduced their variety of services to only one like from APP and TWR to only TWR), and 41 have low experience on their current position but have not changed ATC service recently.

No assumption on the reason for the low experience of the 41 controllers can be made based on the information contained in the questionnaire replies.

The same problem (a too small number of cases) occurred when analysing the kinds of current function (PC, RC, CC and SU, plus the various combinations). The figures are provided in Table E63 in Technical Appendix E. The low number of cases made it impossible to determine whether there are significant differences in the frequencies of positions. Therefore, it is not possible to say whether the group with low experience works on different positions than the group with high experience.

Further explanations why these 54 ATCOs have low experience cannot be derived from the available data. However, some interesting differences between the two groups can be discussed.

Just as for the old group there is also a slight difference in the mean age between the group with low experience and that with average to high experience. However, in the middle-aged group the controllers with low experience are one year younger, on average, than their colleagues with more experience (see Tables E64 and E65 in Technical Appendix E). The group with low experience perceives the start of negative ageing impacts happens 4,19 years later than the group with average to high experience. This is a highly significant difference (see Tables E66 and E67 in Technical Appendix E).

The middle-aged controllers with low experience on their current position have on average less aircraft per hour in the sector in which they mostly work. This difference in the mean number of aircraft per hour of the average to highly experienced group is 6,74, which a T-Test confirmed to be significant (see Tables E68 and E69 in Technical Appendix E).

Regarding other duties supplementing the operational tasks, the group with low experience has significantly less frequently other duties as institutional or simulator instructor, less duties in other training projects and also less duties as supervisor or watch manager (see Tables E70 to E75 in Technical Appendix E). Finally, this group rated the negative influence of ageing as more recognizable on the radar position (see Tables E76 and E77 in Technical Appendix E).

No significant difference was found for the following variables: direction of the influence of ageing (positive, neutral or negative), job demand, compensating power of experience, hours per week spent on other duties, occurrence of technological change at the workplace and number of validations.

Table 8 supplies a summary of the characteristics of the two groups with low experience on current position.

To sum it up, in both the middle-aged and old groups it can be assumed that about one fourth of the controllers (24% in the middle-aged group and 27% in the old group) have a low experience on their current position because

they have changed the ATC service recently. For the remaining three fourth the reasons for this low experience remain unclear.

Table 8: Characteristics of the middle-aged and old controllers with low experience on current position

The middle-aged group*	The old group**
Is slightly younger (one year)	Is slightly older (1,5 years)
Perceives that negative ageing impacts start 4,19 years later	Perceives the impact of ageing, both positive and negative, more extreme
Has lower peak traffic per hour (6,74 aircraft less)	Perceives night shifts more demanding
Is less involved in training tasks (except OJT) and supervisory tasks	Perceives the negative ageing impacts more recognisable on the radar position and in high traffic load situations
Perceives the negative ageing impacts more recognisable on the radar position	

* This column compares controllers with low experience to controllers with average to high experience on their current position **within the group of middle-aged ATCOs**.

** This column compares controllers with different levels of experience on current position **within the group of old ATCOs**.

3.2.9 The perception of other influencing factors

3.2.9.1 Background

Age and experience are not isolated aspects. As it became clear in the earlier sections, there are many other factors interacting with the age of controllers. So far, these context factors have been concluded from inferential statistical evaluations. This section provides data on how controllers perceive the impact of influential factors if they are directly asked to rate their importance. Based on the explorative interview study, four factors were identified which appeared to have an impact on job performance and also on how strongly negative ageing can be felt. These four influencing factors are part-time work, radar/executive position, traffic load and motivation.

The questionnaire covered the four factors by asking for a rating of the following statements:

- working part-time (partly on position - partly other tasks like training) has an influence on my performance;
- the negative effects of age are stronger on the radar (executive) position;
- the negative effects of age are stronger in high traffic load situations;
- high motivation supports me in doing a good job.

The answers had to be given on a six-point rating scale ranging from 'very much disagree' to 'agree very much' (see also Section 6 in the appended questionnaire). A low value indicates a low agreement (1='very much disagree'), a high value indicates a high agreement (6=agree very much').

3.2.9.2 Results

For all four items the agreement of controllers is rather high. For all of them together it achieves a value of 3,83 for the statement on part-time work, of 3,72 for the impact on the radar position, of 4,13 for high traffic load situations and of 5,10 for motivation. The value of 4 represents the verbal statement 'agree'. Therefore, all ratings given by the controllers can be seen as a confirmation of the importance of the four factors. Figure 21 below presents the findings. The turquoise line represents the overall sample.

Also visible in Figure 21 is the great similarity of the ratings for the three age groups. There is hardly any deviation between the groups. Only the last item about the importance of motivation shows a slight deviation of the young group. It appears that young controllers rated the importance of motivation for doing a good job even higher than the other two groups. The exact data depicted in Figure 21 can be found in Technical Appendix E, Table E78.

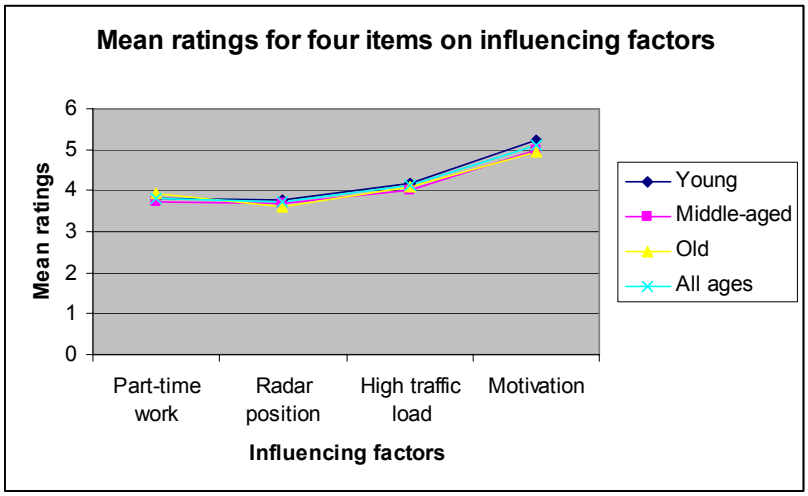

Figure 21: Mean ratings of four items on influencing factors for the three age groups and the complete sample

For a more direct comparison of the three age groups the data is rearranged in Figure 22 below. Indeed, there are only very little differences between the ratings of the three groups. Only for the item on motivation the young groups has a slightly higher rating.

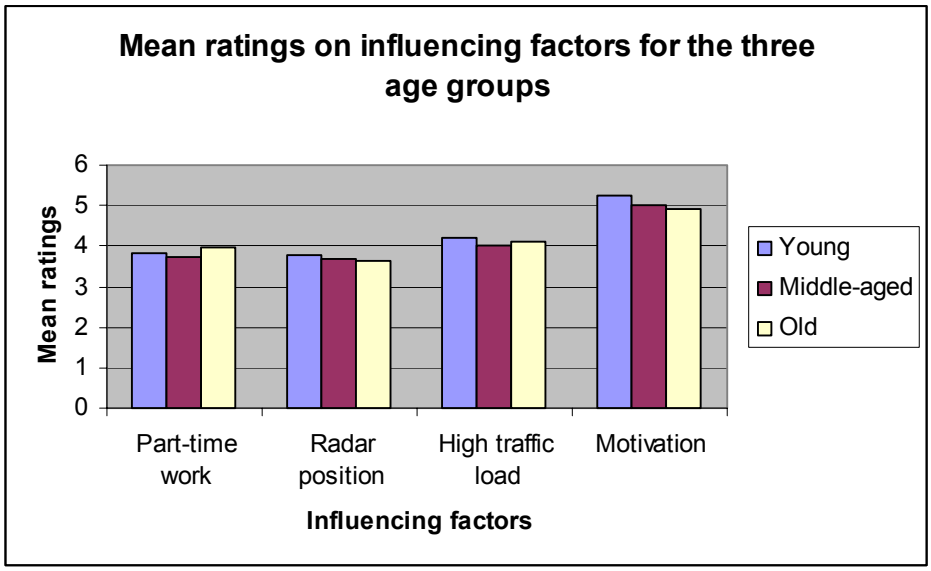

Figure 22: Mean ratings of four items on influencing factors for the three age groups

Although the ratings of the three groups appear to be almost identical, a Kruskal-Wallis test for k independent samples was done to determine any difference between the mean ratings of the three age groups (see Table E79, Technical Appendix E). It resulted in only one significant difference for the item on motivation.

The subsequent Mann-Whitney U-Tests confirmed a significant difference between the young group and the middle-aged and old groups (see also Tables E80 to E83 in Technical Appendix E). The young controllers rated the importance of motivation for doing a good job higher than their older colleagues. For the three other items the ratings of the three age groups are equally high.

3.2.10 Interacting context factors

The data gathered by a questionnaire do not meet the requirements of an experimentally designed study. For example, it is not possible to allocate the controllers according to their age to different ATC services. Therefore, the construction of intervening variables (or of factors as they are known in the language of analysis of variance) is somewhat fuzzy and a high error variance has to be expected. Still, there was an attempt to apply analysis of covariance to the data, in order to get a clearer picture of the interactions amongst the context factors.

The results for most of the context factors are disappointing. Table E84 in Technical Appendix E provides an overview of all analyses of covariance conducted within this survey. In almost all cases - there are only very few exemptions, which will be discussed further down in this report - there is only a tiny change in the results once the variance of the intervening variable is taken out. The changes are even too little to identify trends in the data. This result can hardly surprise. Even though analysis of variance is a suitable method for experimental data, it reaches its limits when applied to quasi-experimental data. Furthermore, the sample for this survey is extremely heterogeneous. Basically all possible differences between human beings are present in the data of this survey and cause 'error variance', starting with the geographical region, unit specific aspects, gender, attitudes, payment, shift schedules, just to mention randomly some sources of variance.

The following combinations of variables were analysed and did not show a substantial impact:

- impact of kind of ATC service and current function on age (analysis of variance with two factors: not significant; see also Table E85 in Technical Appendix E);

- impact of prior experience in other ATC services and current function on age (no substantial change with analysis of covariance, see also Table E84 in Technical Appendix E).

Prior experience in other services and experience on current position

This section tries to answer the question whether the controllers' age together with their prior experience in other ATC services have an impact on how long controllers work at their current position. The analysis of covariance indeed revealed an impact of prior experience on the time on the current position. This is not surprising, as both prior experience in other ATC services and experience on the current position correlate strongly with the controller's age (see Sections 3.2.5 and 3.2.8).

Table 9 below summarises the months on the current position before and after eliminating the influence of prior experience in other ATC services.

Table 9: Mean times on current position (in months)

Type of age group	Mean time on position including prior experience (non-adjusted values)	Mean time on position without prior experience (adjusted values)
Young	61,6	58,9
Middle-aged	160,3	162,7
Old	217,9	225,5

The mean times on current position for the three age groups are 61,6 months for the young group, 169,3 months for the middle-aged group and 217,9 months for the old group. After eliminating the impact of prior experience in other ATC services, the following mean ages result in 58,9 months for the young group, 162,7 for the middle-aged and 225,5 for the old group.

Figure 23 below shows the adjusted and non-adjusted values for time on current position.

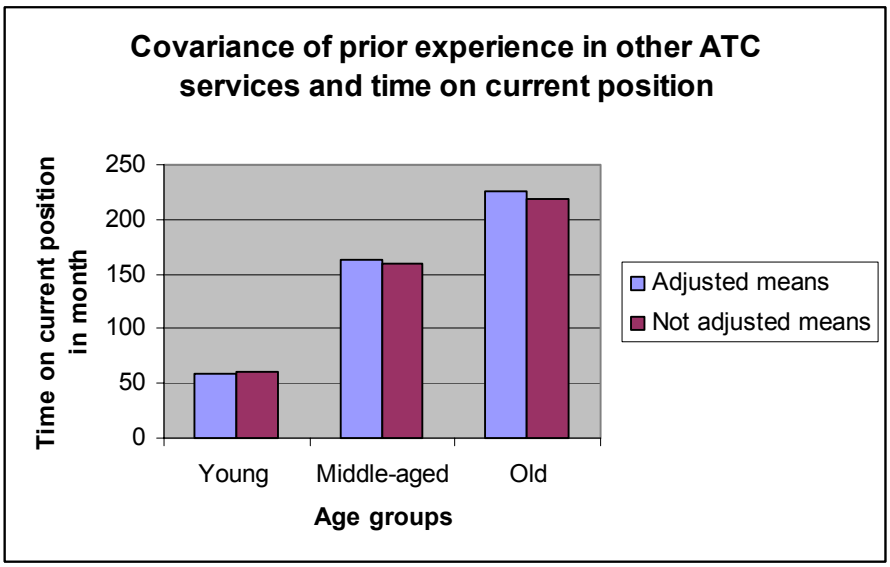

Figure 23: Time on current position for the three age groups before (=non-adjusted) and after (=adjusted) the influence of prior experience has been corrected

The results confirm the assumption that middle-aged and old controllers who have some experience in other ATC services have a slightly shorter experience on their current working position. For young controllers the trend is opposite, possibly because only the 'older' young controllers do have at all prior experience in other services.

3.2.11 Summary

Due to the amount of results presented in this section the summaries per sub-sections are kept brief. This implies a risk of oversimplification. Therefore, in case there is any surprising statement in this summary, just go back to the corresponding sub-sections and check the detailed result descriptions.

- Kind of ATC service: The mean age of controllers varies from service to service. The youngest controllers work in tower control (36,64 years), the oldest controllers combine ACC and TWR (41,31 years). ACC controllers

have a mean age of 37,92 years, APP controllers of 39,85 years and oceanic controllers of 41,13 years.

- Time spent on tasks/duties other than operational: Regarding the kinds of other duty, young controllers are more involved in training-related tasks (especially OJT) whereas middle-aged and old controllers show a higher involvement in supervisory and managerial/administrative tasks, and in selection, performance assessment and incident investigation. Regarding the time spent on these tasks/duties, it can be concluded that the old group spends significantly more time per week on other duties than the young group does.

- Number of validations: The average number of validations per controller is 4,35. No significant difference between the age groups could be found. Instead, the data shows a non-significant trend: older controllers have slightly more validations than the young ATCOs.

- Prior experience in other ATC services: As far as prior experience in other ATC services is concerned, the data shows highly significant differences between the three age groups: the young group has a mean time of 3,22 years of experience, the middle-aged group of 7,19 years and the old group of 10,52 years.

- Part-time work: 23% of the ATCO sample of this survey do part-time work. The young age group works more part-time in the 99-80% category and in the less-than-50%-of-time category. The old age group works more part-time in the 79-50% category.

- Current function: Older controllers work more in combinations of functions involving supervisory or leadership functions (crew chief or supervisor) and they tend to be more involved in functions other than the four ‘classic’ ones. The young group has a higher number of radar controllers and a lower number of planning controllers, but, at the same time, a surprisingly high number of ATCOs in supervisory tasks, and in combinations of supervisory and radar tasks is observed. The high number of young controllers in supervisory functions may be due to the fact that the upper limit of the range of this age group is 36 years. The middle-aged group includes a higher number of cases of combinations involving the function of planning controller.

- Experience on current position versus overall job experience: The older a controller, the higher is his or her overall job experience. The same is true for the experience on current position. However, there is a number of controllers (about 9,18% of the sample) who have a below average time on their current position. From the survey data it is hard to determine why it is so.

- The perception of other influencing factors: The controllers of all age groups agree to the importance of the influencing factors ‘work on radar position’, ‘high traffic load’, ‘doing part-time work’ and ‘motivation’. The

young controllers rated the importance of motivation higher than the other two groups.

- Interactions between the context factors: Only one interaction could be confirmed: middle-aged and old controllers who have some experience in other ATC services have a slightly shorter experience on their current working position.

3.3 Cognitive Ageing versus Gains due to Experience

3.3.1 Introduction

This section deals with the aspects of the questionnaire related to the perception of ageing by the controllers. The opposite effects of impairments due to ageing and of gains due to experience are equally taken into account. The variables, which are evaluated in this section, are listed under 2.3.2.

It was already mentioned in Section 2.5.2, 'Leading questions', that cognitive or mental ageing is a normal process, which concerns all human beings. However, it is not an isolated process; it is accompanied by the counteracting process of gathering experience and knowledge.

According to scientific literature there is a number of negative cognitive developments associated with ageing[8]. A general slowing down in information processing is frequently observed. Declines in some aspects of attention (selective attention, sustained attention and demanding processes in terms of data processing) are common. Many tasks that place a high demand on working memory become more difficult. Long-term memory is sometimes impaired. Spatial reasoning (e.g. perspective taking, mental rotation of objects, spatial memory and environmental learning) gets slower and less accurate with age. Some aspects of problem solving deteriorate with increased age, especially if the problems are complex and unfamiliar.

The counterbalancing power of experience may be a great help to compensate for the above-described declines. Especially people who are experts in their domain have substantial advantages in their area of expertise. Expertise refers to the knowledge and skills of well-experienced operators or experts in a certain subject. Below are the six main characteristics of expertise:

- structured, principled knowledge (i.e. a broad knowledge about their subject);
- proceduralised knowledge (i.e. they have useful rules in memory to know what to do, how to do it and when to do what);
- skilled memory (i.e. experts use rapid and accurate strategies to improve their short-term memory by making use of their long-term memory);

[8] For further details on these issues see also EATMP (2003a).

- automaticity (i.e. the execution of highly trained tasks happens automatically, without requiring much conscious attention);
- effective problem representation (i.e. they spend extensive time on analysing the problem and, by doing so, increase the chance of solving it);
- strong self-regulatory skills (i.e. experts monitor their problem solving by predicting the difficulty of a problem, allocating time appropriately, noting their errors or failures and checking possible solutions).

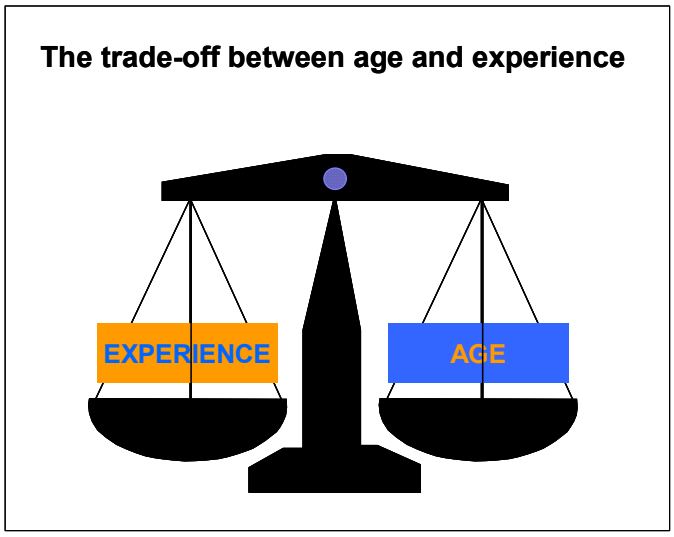

Figure 24: The counterbalancing effect of ageing and experience

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. Figure 24 above provides a simple picture of these counterbalancing processes.

The following sections will transfer these scientific findings to the world of ATM. The questionnaire tried to identify the negative and positive processes which concern air traffic controllers in their day-to-day job.

3.3.2 The perception of ageing processes and experience

3.3.2.1 Background

One of the main questions of this survey is whether controllers at different ages have a different perception of the process that come with increased age. On the one hand there are negative aspects associated with ageing, like declines in certain areas of cognitive performance, and on the other hand there are positive developments due to experience.

As this survey is mainly interested in the cognitive development associated with age and experience, most of the items address mental tasks. However, some items are concerned with self-confidence, health, stress and recovery, as these issues are of high importance with regard to ageing. They provide a broader context to the mental side of the work and must not be neglected.

The questionnaire contained 26 items addressing the counterbalancing processes of age and experience. Controllers were asked to rate the 26 statements on a six-point rating scale ranging from 'very much disagree' to 'very much agree' (see appended questionnaire, Section 4.6). 'Very much disagree' was assigned value 1, 'disagree' value 2, 'somewhat disagree' value 3, 'somewhat agree' value 4, 'agree' value 5 and 'very much agree' value 6. Consequently a high mean rating (i.e. high value) like 5,24 reflects a high agreement, whereas a low value like 2,58 points to disagreement.

The statement started with the introductory phrase 'With further job experience and an older age…' and continued with the 26 different items to rate. The items are supposed to cover both the positive and negative aspects of increased age and experience.

The following twelve items aimed at the positive side of experience:

1. ... I have better knowledge of situations and solutions.
2. ... I work more safely.
3. ... my self-confidence is higher.
4. ... I know the 'tricks' of the job.
5. ... my efficiency usually increases.
6. ... I am better at managing my workload.
7. ... my work becomes routine for me.
8. ... my ability to anticipate the traffic development improves.
9. ... I become better at handling unusual situations and emergencies.
10. ... I become better at planning
11. ... I am better at prioritising the tasks.
12. ... I have a broader context knowledge (e.g. about aircraft performance, weather, etc.).

The following fourteen items addressed the more negative sides of ageing:

13. ... My working speed decreases.
14. ... health problems increase (e.g. eyesight gets worse, high blood pressure, back problems, etc.).
15. ... I can handle less traffic.
16. ... my flexibility decreases.
17. ... the job in general gets more demanding for me.

18. ... learning gets more difficult for me.
19. ... my self-confidence is lower.
20. ... multitasking (i.e. doing more than one thing at a time, e.g. strip writing and making a phone call) gets more difficult for me.
21. ... my mental traffic picture is more limited.
22. ... I experience problems with decision-making.
23. ... it becomes harder for me to cope with stress.
24. ... my memory gets worse.
25. ... it gets more difficult to keep attention over a sustained period of time.
26. ... my recovery after working hours takes longer.

In the questionnaire the two groups of items were presented in a mixed sequence to minimise answering biases. Furthermore, the controllers were asked to rate the items from the perspective of their current age, thinking of their own experience and not taking older colleagues as a reference.

3.3.2.2 Results

The average ratings for the three age groups on the 26 items are displayed in Figure 25 below.

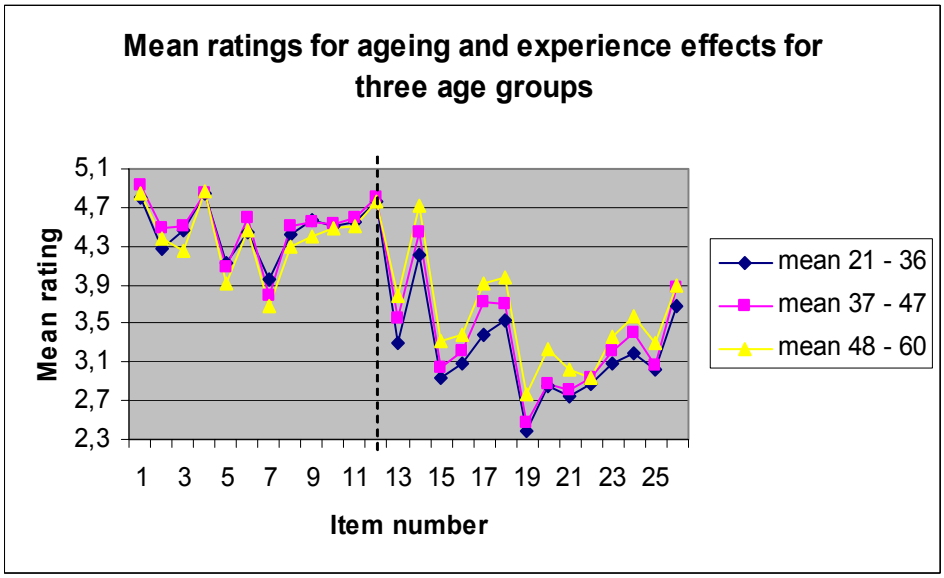

Figure 25: Mean ratings for 26 items on ageing and experience for the three age groups

Note: The data points are isolated mean ratings and are not connected to each other. The lines between the points merely improve the readability of the figure and help to recognise which data points belong to which age group.

Means, standard deviations and ranges per age group for each item are available in Technical Appendix F, Table F1. Generally, the agreement to the more positive experience-related items (numbers 1 to 12 in Figure 25 above) is stronger than to the more negative ageing items (items 13 to 26 in Figure 25). Items 1 to 12 range between 'somewhat agree' and 'agree', with one exception (item 'my work becomes routine for me').

On the other hand, most of the ageing-related items have a mean value around 3 ('somewhat disagree'). Exceptions with a higher agreement are the items 'health problems increase', 'the job in general gets more demanding for me', 'learning gets more difficult for me' and 'my recovery after working hours takes longer'. The item with the lowest agreement is 'my self-confidence is lower' (mean value 2,48).

Although in Figure 25 the three different curves seem to be rather similar, a Kruskal-Wallis Test for k independent samples revealed seventeen significant differences between the mean ratings (for detailed results see Table F2, Technical Appendix F).

Eleven items differ highly significantly (α=1%) in their mean rating:

- ... My working speed decreases.
- ... health problems increase (e.g. eyesight gets worse, high blood pressure, back problems, etc.).
- ... I can handle less traffic.
- ... my flexibility decreases.
- ... the job in general gets more demanding for me.
- ... learning gets more difficult for me.
- ... my self-confidence is lower.
- ... my work becomes routine for me.
- ... multitasking (i.e. doing more than one thing at a time, e.g. strip writing and making a phone call) gets more difficult for me.
- ... my mental traffic picture is more limited.
- ... my memory gets worse.

Six items still reach a significant level (α=5%):

- ... my self-confidence is higher.
- ... my efficiency usually increases.
- ... I am better at managing my workload.
- ... my ability to anticipate the traffic development improves.
- ... it becomes harder for me to cope with stress.
- ... it gets more difficult to keep attention over a sustained period of time.

Interestingly, all the highly significant effects concern the negative aspects of ageing, maybe because the positive aspects of experience can be already

felt early in the career of a controller. The learning curve is much steeper during the first years on the job and becomes less and less steep with increasing time. After a few years of doing the operational job a rather high level of experience is reached and remains on a high level from there onwards. The process of ageing, however, starts later in life and may have a different dynamic than that of the processes associated with learning and gathering experience. Therefore, the difference between an older and younger group of subjects may be greater with regard to ageing effects.

The Kruskal-Wallis test only confirms the existence of a difference. However, it is not able to provide information on the direction of the difference. Therefore, supplementary Mann-Whitney U-Tests comparing each of the three age groups with one another (for details see Tables F3 to F5 in Technical Appendix F) were calculated and confirmed the following differences between the age groups.

The results confirm many effects already known from literature: decrease in information processing speed, and both health problems and general job demand increasing steadily with age. Moreover, other negative developments are felt more strongly by older controllers: they feel they can handle less traffic, learning gets harder, their self-confidence is lower, multitasking becomes more difficult, their mental traffic picture is more limited and sustained attention becomes more difficult.

Table 10: Significant differences between the three age groups regarding their rating of items 1 to 26 on age and experience

Significant differences between the age groups[9]	**Items on age and experience and their interpretation in the light of the test for significance**
The old group agrees more strongly to these statements than the middle-aged and young groups, and the middle-aged group agrees even more strongly than the young group.	…My working speed decreases: With increased age controllers feel their working speed decreases. …health problems increase (e.g. eyesight gets worse, high blood pressure, back problems, etc.): With increased age health problems of controllers increase. …the job in general gets more demanding for me: With increasing age the job is perceived more demanding.
The old age group has a higher agreement to these statements than the other two groups.	…I can handle less traffic: Old controllers feel they have a lower capacity for traffic handling than middle-aged and young controllers. …learning gets more difficult for me: For older controllers it gets more difficult to learn than for middle-aged and young controllers. …my self-confidence is lower: Older controllers have a lower self-confidence than middle-aged and young controllers.

[9] The exact figures can be found in Table F6 in Technical Appendix F.

Significant differences between the age groups[9]	Items on age and experience and their interpretation in the light of the test for significance
	…multitasking (i.e. doing more than one thing at a time, e.g. strip writing and making a phone call) gets more difficult for me: Compared to the middle-aged and young controllers multitasking becomes more difficult for old controllers. …my mental traffic picture is more limited: Old controllers feel that their mental traffic picture is more limited than that of middle-aged or young controllers, …it gets more difficult to keep attention over a sustained period of time: Older controllers feel it is more difficult for them to keep sustained attention than it is for middle-aged or young controllers.
The old age group has a higher agreement to these statements than the young group.	…my flexibility decreases: Old controllers feel they are less flexible than young controllers. …It becomes harder for me to cope with stress: Old controllers perceive it becomes harder for them than for young controllers to cope with stress.
The old age group agrees less to this statement than the other two groups do.	…my self-confidence is higher: Young and middle-aged controllers have a higher self-confidence than old controllers.
The old age group agrees less to this statement than the young group does.	…I become better at handling unusual situations and emergencies: Young controllers feel they become better at handling unusual situations and emergencies.
Both the middle-aged and old groups have a higher agreement to this statement than the young group.	…my memory gets worse: Both middle-aged and old controllers feel their memory becomes worse.
The middle-aged group agrees strongest to this statement.	…I am better at managing my workload: Middle-aged controllers feel they are the best at managing their workload.
The middle-aged group agrees more strongly to this statement than the old group.	…my ability to anticipate the traffic development improves: Middle-aged controllers feel their ability to anticipate the traffic improves.
The young age group agrees more strongly to this statement than the middle-aged and old age groups.	…my work becomes routine for me: To a higher degree than middle-aged and old controllers young controllers perceive their work as routine.
The young age group has a higher agreement to this statement than the old group.	…my efficiency usually increases: Young controllers believe they are more efficient than old controllers.

Interestingly, younger controllers agree more strongly to the statement ‘my work becomes routine for me’, even if they have not spent as much time on their job yet as have older controllers. The increased experience seems to increase the experience about the variability of the ATCO job accordingly. Surprising is also the fact that young controllers feel a stronger increase in efficiency than do older controllers. This would contradict the fact that a gain

in efficiency usually comes along with increased experience. It may be that young controllers translated ‘efficiency’ as ‘working speed’. From this point of view they may be right.

3.3.3 The perception of gains due to experience

3.3.3.1 Background

The picture on job performance of ATCOs would not be full if only the core tasks of the job, in a strict sense, would be taken into account. Only for isolated mental functions a decline is proven by experimental research. For overall job performance the picture is much more complex. Job performance consists of many components, some of which decrease with ageing, some of which increase and some of which stay the same. The questions on gains due to experience therefore include additional aspects of the job like leadership, training tasks, managerial tasks and overall planning skills. From research on job performance it is well-known that these kinds of skill form an important part of overall job performance and must not be neglected in the assessment.

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

In the questionnaire subjects were asked to give their opinion on the question whether older controllers are better at certain tasks (‘Do you believe older controllers are better at certain tasks? Please indicate your view on the following statements.’). The statements were as follows:

- older controllers are better as supervisors or in other leadership positions than younger controllers;
- older controllers are better than younger controllers at handling unusual situations or emergencies;
- older controllers are better as instructors and trainers than younger controllers;
- older controllers are better at planning the traffic than younger controllers;
- it is rather a question of individual differences; more than age it is a question of where the controllers’ strengths are;
- older controllers are not better at certain tasks.

Again, these items were to be rated on a six-point rating scale ranging from 'very much agree' to 'very much disagree'.

3.3.3.2 Results

The mean ratings per item for the three age groups are depicted in Figure 26 below. Again, the higher the mean rating the higher is the agreement with the statement. Detailed data on means, standard deviations and range can be found in Table F7 in Technical Appendix F.

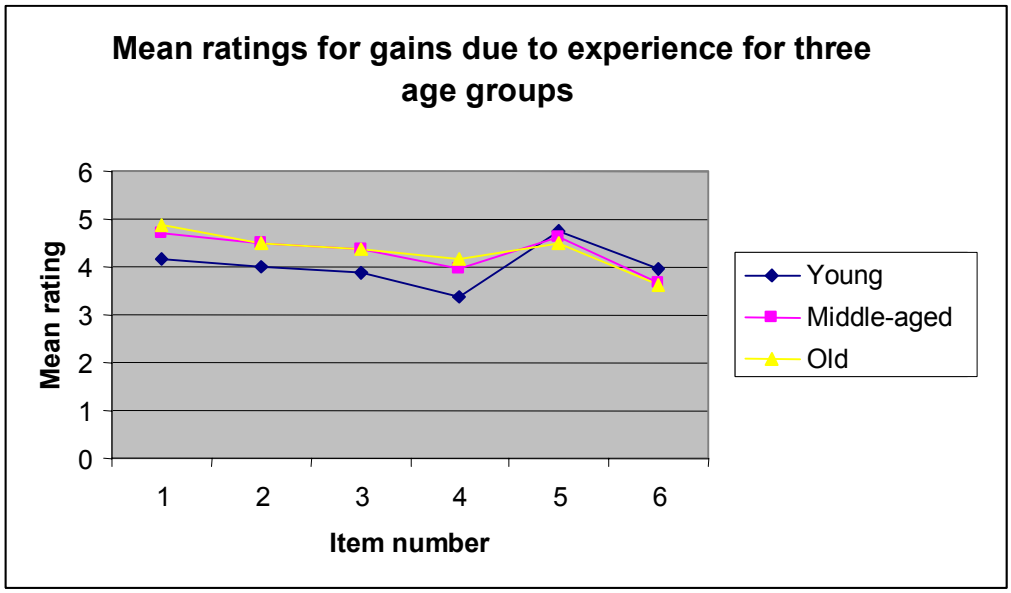

Figure 26: Mean ratings on items on gains due to experience for the three age groups

The figure shows that the general agreement to the six items is rather high. The overall means for all controllers range from 3,70 to 4,66 (for details see Table F12, Technical Appendix F). These values can be interpreted in a way that on average there is rather an agreement with the items ('somewhat agree' on the rating scale equals value 4). However, Figure 26 also shows that there are differences between the three age groups in the strength of their agreement. Especially for the first four items, dealing with leadership, unusual situations, training and planning tasks, the young group agrees less than the other two groups. On the contrary, the middle-aged and old groups have an equally positive assessment of these statements.

The Kruskal-Wallis Test for k independent samples was calculated to check for significant differences. For all six items highly significant differences (α=1%) between the mean ratings were found (for details see Table F8 in Technical Appendix F).

The comparison of the three age groups with supplementary Mann-Whitney U-Tests revealed the following differences between the groups (for details

see Tables F9 to F11 in Technical Appendix F) summarised in Table 11 below.

The deviations in the assessment of the items on gains due to experience between the three age groups show the difference in subjective perception of these items. Older controllers feel they become better at a number of tasks, younger controllers do not feel they are better at these tasks. At this stage of research it is impossible to come to a conclusion whether one or the other is right. Only objective performance measurement could provide an answer. However, this result is a clear vote against the use of peer assessments in research on job performance because the assessments will be biased depending on who is asked to do the peer rating.

Table 11: Significant differences between the three age groups (21 to 36, 37 to 47, and 48 to sixty years) regarding their rating of items 1 to 6 on gains due to experience

Significant differences between the three age groups*	Items on gains due to experience
The middle-aged and old groups have a higher agreement to these statements than the young group.	Older controllers are better as supervisors or in other leadership positions than younger controllers. Older controllers are better than younger controllers at handling unusual situations or emergencies. Older controllers are better as instructors and trainers than younger controllers.
The old group agrees more strongly to this statement than the middle-aged and young groups, and the middle-aged group agrees more strongly than the young group.	Older controllers are better at planning the traffic than younger controllers.
The young group agrees more strongly to this statement than the old group.	It is rather a question of individual differences; more than age it is a question of where the controllers' strengths are.
The young group agrees more strongly to this statement than the middle-aged and old groups.	Older controllers are not better at certain tasks.

* The corresponding exact figures can be found in Table F12 in Technical Appendix F.

Another biasing factor may be the personal experience with the item, e.g. difference of rating leadership as the one performing or receiving it. Usually, the younger controllers are subjects of training or of leadership; therefore their attitude towards the persons in charge may be more critical. With more and more experience in the active role this critical view might become more realistic.

3.3.4 The perception of the onset of ageing

3.3.4.1 Background

Of great interest is the question at what age negative ageing effects, if there are any at all, start. Psychological laboratory research dealing with basic mental processes, such as signal detection, information processing speed or attention, has given rather frustrating results: some authors set the start of mental decline as early as in the twenties of the life span. However, these isolated findings are of limited importance for everyday life. It is more interesting to find out at what point in time the compensating power of experience may be overtaken by the negative ageing development.

The questionnaire asked three questions about the perception of the onset of the ageing process. The first question addressed the compensating power of experience, the second question the direction of the influence of ageing (positive, neutral or negative), and the third one asked the start age of negative ageing impacts.

3.3.4.2 Results

Firstly, the statement 'Experience helps to compensate for ageing effects' was to be rated on the six-point rating scale from 'very much disagree' to 'very much agree'. This item achieved a high rating value (4,64 on average), meaning rather an agreement from the participating controllers to the statement above. The comparison of the three age groups as to the mean rating of this item shows significant differences. The average rating of the young group is 4,43 (std=1,07), that of the middle-aged group is 4,85 (std=0,84) and that of the old group 4,89 (std=0,85). These average ratings are displayed in Figure 27. For more details see also Tables F13 to F16 in Technical Appendix F.

A Kruskal-Wallis test for k independent samples revealed a highly significant difference (α=1%) between the mean ratings (see Table F17 in Technical Appendix F). The supplementary Mann-Whitney U-Tests proved highly significant differences between the young and middle-aged groups, and the young and old groups. The young group agrees significantly less to this statement than the middle-aged or old age groups (see also Table F18 in Technical Appendix F).

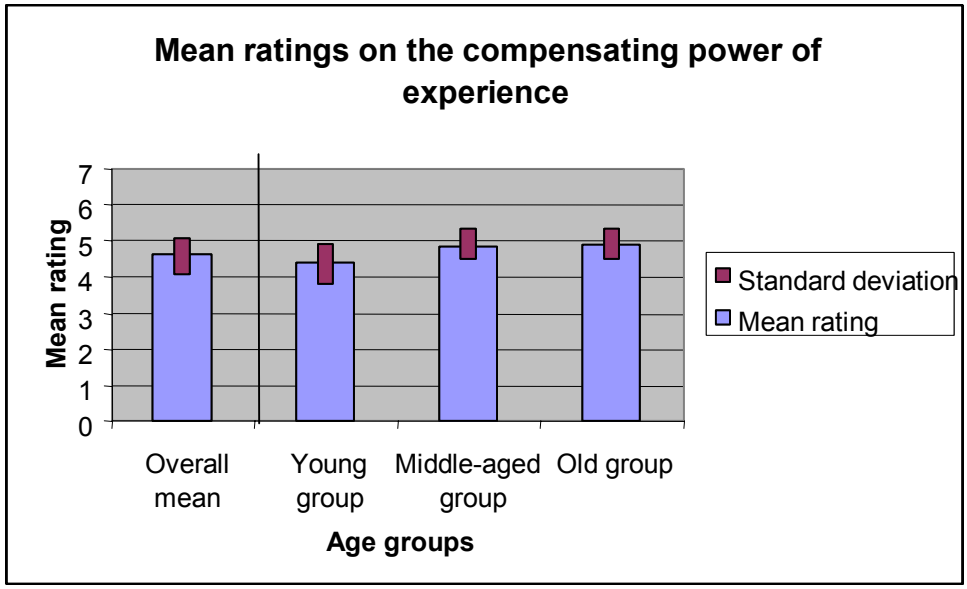

Figure 27: Mean ratings on the compensating power of experience by the three age groups and overall by all controllers

Middle-aged and old controllers feel the compensating power of experience more strongly than do young controllers.

Secondly, the controllers were asked about the direction of the impact of ageing on ATCO's job performance ('What kind of influence can ageing have on an air traffic controller's job performance after the age of forty?'), with choice between the answers 'positive', 'neutral', or 'negative'. Most of the controllers see a negative impact of age on job performance (507 answers); about one third sees no influence (335 answered 'neutral') and only 195 see a positive influence.

Figure 28 below shows these facts. Looking at the three age groups separately (also in Figure 28), it appears that there are differences in the distribution of the answers over the categories 'positive', 'neutral' or 'negative'.

As this is categorical data, a Chi^2 test was used to check whether the observed frequencies (i.e. the number of answers per category – positive, neutral, negative – for the three age groups) deviated from what would have been theoretically expected if there had been no link between the age of the subjects and their answer to this question. The Chi^2 tests revealed a highly significant link between the age of the controllers and their answers (for the detailed test results see Tables F21 to F23 in Technical Appendix F). For the interpretation of this finding it is necessary to compare the observed frequencies with the theoretically expected ones. Table 12 provides these values.

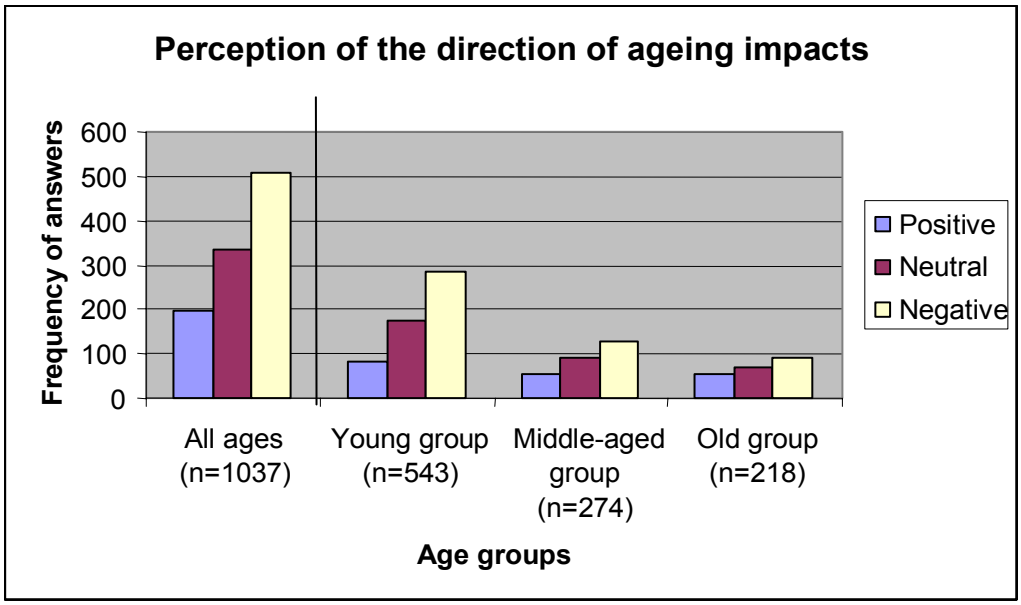

Figure 28: Perception of the direction of ageing impacts (positive, neutral or negative) by all controllers and by the three age groups separately

Note: The exact figures are available in Tables E19 and E20, Technical Appendix E.

Table 12: Observed and expected frequencies for the three categories of answers (positive/neutral/negative) for the three age groups

Type of age group	Type of frequency	Influence of ageing			Total
		Positive	Neutral	Negative	
Young	Observed	83,00	174,00	286,00	543,00
	Expected	101,73	175,73	265,43	543,00
Middle-aged	Observed	54,00	93,00	127,00	274,00
	Expected	51,35	88,65	134,00	274,00
Old	Observed	57,00	68,00	93,00	218,00
	Expected	40,83	70,53	106,53	218,00
Total	**Observed**	194,00	335,00	506,00	1035,00
	Expected	194,00	335,00	506,00	1035,00

The subsequent Table 13 provides a summary of the differences between observed and expected frequencies in the respective categories. Rather low deviations can be found for the middle-aged group, for positive and neutral influence answers. Furthermore, the neutral answer category shows low deviations for all three age groups.

Table 13: Summary of the differences between observed and expected frequencies of the three age groups for influence of ageing

Type of age group	Influence of ageing		
	Positive	Neutral	Negative
Young	-18,8	-1,8	+20,5
Middle-aged	+2,6	+4,3	-7,0
Old	+16,1	-2,6	-13,6

The young and old age groups show strong deviations for both the positive and negative answers, even though these have opposite directions. Whereas the young controllers have many less positive answers than expected (-18,8) the old controllers have many more positive answers than expected (+16,1). At the same time the young ATCOs have many more negative answers than expected (+20,5) and the old ATCOs have many less negative answers (-13,6). These facts can be interpreted in a way that older controllers perceive ageing more positively than younger controllers, and young controllers perceive it more negatively.

Thirdly, the controllers were asked about the onset of ageing ('If your last answer was 'negative', at what age do you think performance starts to decline?').

Depending on the formulation of the question only 485 subjects among all questioned subjects answered it (only those controllers who perceive that ageing has a negative impact). The average age for the start of ageing is 44,83 years (std=5,63), the earliest age is thirty and the latest age sixty (see Figure 29 below).

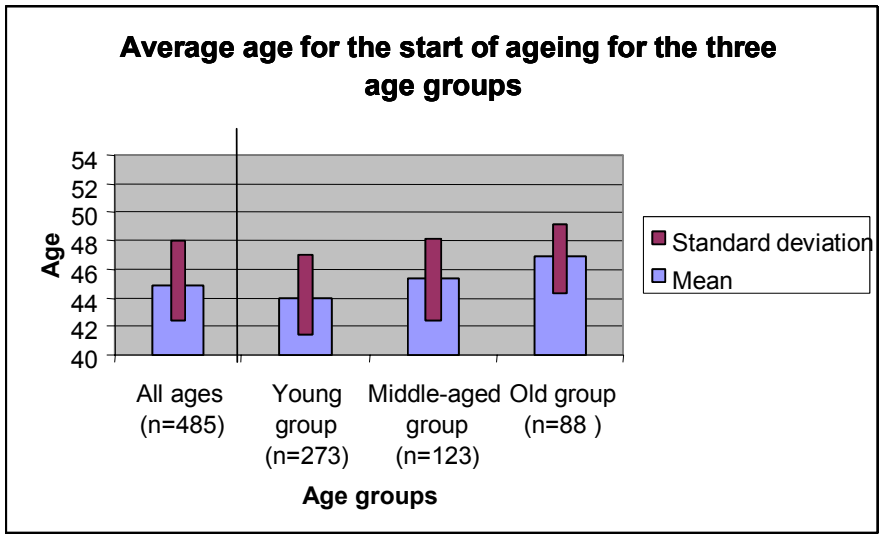

Figure 29: Average age for the start of ageing for the whole sample and the three age groups

For significance purposes a one-way ANOVA was calculated to check the differences between the means of the three age groups (see Table F25 in Technical Appendix F). A highly significant difference was revealed.

Supplementary Tukey-HSD tests for multiple comparisons proved significant differences between the young group and the middle-aged and old groups. This means the young group sets the start of ageing earlier than the middle-aged and old groups. Furthermore, the mean of the middle-aged group differs significantly form that of the young group. Middle-aged ATCOs indeed perceive the onset of ageing later than the young group. Finally, the mean of the old group differs from that of the young group, in that older controllers perceive the start of ageing significantly later than younger controllers.

3.3.5 Summary

- The perception of ageing processes and experience: With increasing age controllers feel the negative impacts of ageing more strongly than their younger colleagues. They have clearly a stronger agreement to the statements concerned with the negative side of getting older. All controllers show an agreement to the positive experience related items. These items may therefore reflect the general process of acquiring the skills of a good air traffic controller.

- Gains due to experience: The assessment of gains due to experience differs depending on the controllers' age. Middle-aged and old controllers agree that they become better at a number of tasks, while young controllers do not find that their older colleagues become better.

- Perception of the onset of ageing: Middle-aged and old controllers feel the compensating power of experience more strongly than young controllers. Older controllers perceive ageing more positively than younger controllers. The onset of ageing is regarded as being at 44,83 years on average. However, this age differs depending on the age of the controllers who answer the question: the start of ageing is later in the opinion of controllers with increased age. This means that for older controllers ageing starts later and for younger controllers it starts earlier.

3.4 Job Demand and Strain

3.4.1 Introduction

Job demand and strain is the second broad area of interest with respect to ageing. Occupational age structures throughout many professions show three strong tendencies amongst older employees:

- Firstly, older workers 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 that 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 (for example working on a conveyer belt), or by time pressure resulting from a piece-rate payment.

- Thirdly, the older employee's body becomes less and less tolerant towards the demanding aspect of night shifts. Although the ATCO job is not so much demanding physically, the second and third trends – time pressure and night shift – may well be issues for ageing controllers.

Job demand is a very complex construct and no final definition of this term amongst human factors experts exists. There are two basic approaches to the research in job demand:

- One looks at the subjective side of job demand, that is the felt demand by an individual. To make this point a bit clearer an example may help. The same number of aircraft in a certain period of time, with exactly the same level of complexity in the same sector may for one controller be a heavy demand and very exhausting to work while it is the pure pleasure and just the right level of excitement of another one. This felt demand depends on many factors. The overall skill level plays an important role, the physical condition of a controller - he or she may have a cold that day - and the daily form has a high influence, but also current working conditions like noise, lightning, shift roster, team quality and many other factors influence the subjectively felt job demand.

- The second approach to job demand is to take objective measures of the demand. There are many possible measures applicable. Frequently used are, for instance, the number of aircraft handled in a certain period of time, the complexity (though complexity may be defined in a concrete case) and traffic load of a sector, or the fuel burn of traffic passing a sector. All these measures are worth being discussed from a usefulness and reliability point of view[10]. Nevertheless, for pragmatic reasons this study used peak traffic load per hour in a sector as indicator for objective job demand. Further explanations will be detailed in Section 3.4.3.

3.4.2 The perception of job demand

3.4.2.1 Background

Subjective job demand consists of various components. This study took those aspects into account which could be expected to be ageing-sensitive. Ageing-sensitive means that some features of job demand may not be

[10] Another work package of the SHAPE Project on mental workload, being currently carried out, is developing a new tool for assessing controllers' mental workload.

influenced by the age of the person working and some may change due to increased age:

- General job demand was used as an overall indicator for job demand.
- The demand of peak traffic periods was the second indicator. Already in Section 3.2.2 the results confirm that older controllers find it harder to cope with stress. As a peak traffic period is a good example of a stressful situation, the demanding aspect of a peak may also increase with age.
- Thirdly, the high demand of a busy summer season was used as another indicator to check whether this sustained demand over a longer period is also higher for older controllers.
- Finally, the demand of night shifts was asked for, as literature puts strong arguments forward that night shifts become harder and harder to cope with the older one gets.

This survey covered the four areas of subjective job demand with the following questions:

- How demanding is your job in general for you?
- How demanding are peak traffic periods during a working day for you?
- How demanding is the summer season with high traffic for you?
- How demanding is working night shifts for you?

The answers to these four questions had to be given on a six-point rating scale ranging from ‘very low’ to ‘very high’ (see also Section 5 of appended questionnaire). A low value indicates a low job demand (1=’very low’), a high value indicates a high job demand (6=’very high’).

3.4.2.2 Results

Figure 30 shows the results. With a mean rating of 3,91, the demand of the job in general is, for all age groups, rather high; the demand of the job in periods of peak traffic and during the summer season, respectively with 4,35 and 4,40, is even higher, whereas the demand of night shift working received a lower rating, with 3,75 (for more details see Table G1 in Technical Appendix G.

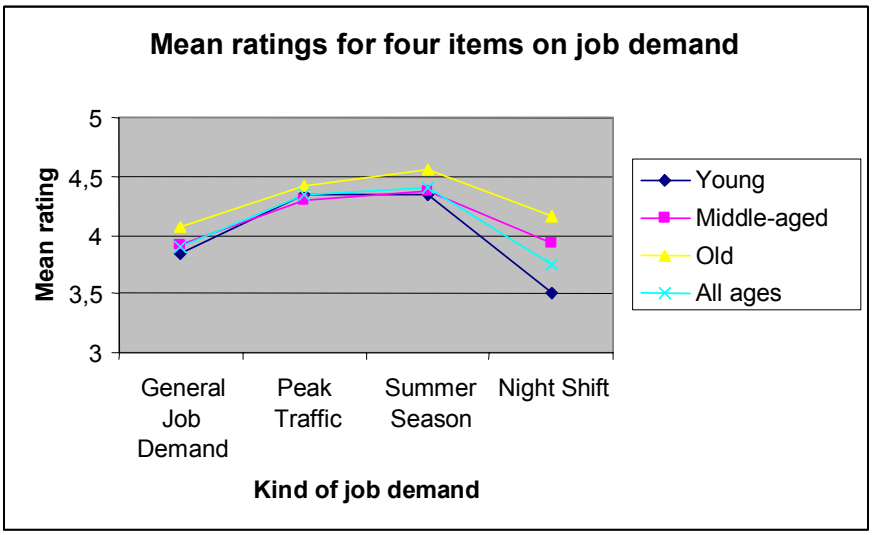

Figure 30: Mean ratings for four items on job demand for the three age groups and the overall group

To check the differences between the mean ratings of the three age groups a Kruskal-Wallis test for k independent samples was calculated (see Table G2 in Technical Appendix G). Three significant differences in means were identified: for demand of job in general and for night shift demand the mean ratings differ quite significantly (α=1%), and for demand of summer season the mean still differs significantly (α=5%). No difference was found for demand of peak traffic.

Figure 31 below compares the mean ratings for the four items on job demand per age group. The greatest difference is visible for the demand of night shift, whereas the three other kinds of job demand show only slight deviations.

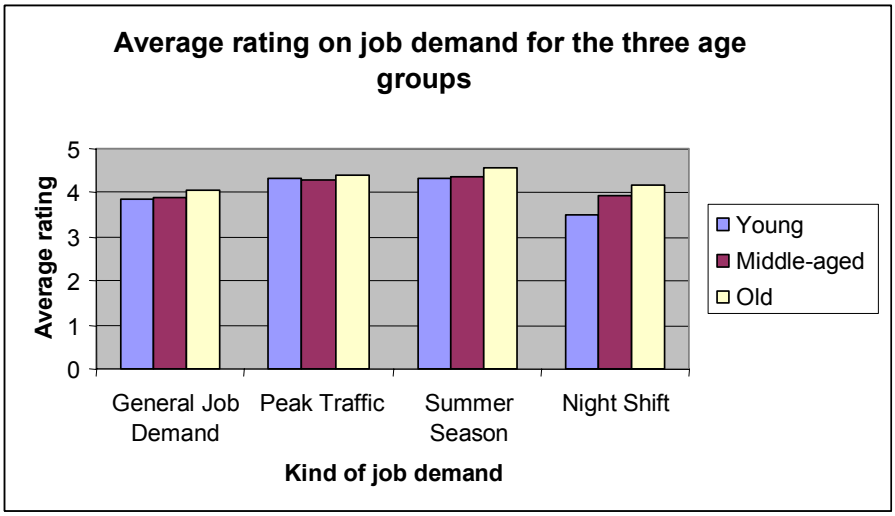

Figure 31: Comparison of the mean ratings for the four items on job demand between the three age groups

The results of supplementary Mann-Whitney U-Tests (see Tables G3 to G6 in Technical Appendix G) are summarised in Table 14 below.

The data confirms a continuous increase in demand of night shifts with age. Older controllers feel a higher general job demand and a higher demand during summer season. So far, the results are in good agreement with literature. Surprising is the finding that the daily peak traffic does not place a higher demand on older controllers. Obviously, they have developed appropriate strategies to cope with this form of demand.

Table 14: Significant differences in the mean ratings of four items on job demand between the three age groups

Significant differences between the age groups*	Items on job demand
The old group rated this item higher than the middle-aged and young groups.	How demanding is your job in general for you? The job in general is more demanding for the old age group than for the middle-aged or young groups. How demanding is the summer season with high traffic for you? The summer season is more demanding for older controllers than for young ones.
The old group rated this item higher than the middle-aged and young groups; the middle-aged group rated it higher than the young group.	How demanding is working night shifts for you? With increased age working night shifts gets more and more demanding.
No significant difference in the mean ratings could be found between the three groups.	How demanding are peak traffic periods during a working day for you? Peak traffic is for all age groups equally demanding.

* The corresponding exact figures can be found in Table G6 in Technical Appendix G.

3.4.3 Peak traffic load per hour in a sector

3.4.3.1 Background

Objective data on job demand is hard to gather through a questionnaire. The only practicable measure is the peak traffic load per hour on a working position as an indicator of workload. As most controllers have validations for more than one working position or sector, this survey aimed to identify the job demand for those sectors in which controllers spend most of their time. This approach, more than that consisting of only asking for the peak demand on any of their working positions, appeared to provide a reliable picture of their actual demand.

The controllers were asked to name the three working positions which they mostly worked. They were then asked to rate these in descending order (most, medium and least). The third question was about the peak traffic load of these three working positions (see also the appended questionnaire,

Sections 1.11 to 1.13). As this part of the questionnaire was rather complex it might be the reason why the number of missing data is so high. Missing answers indeed range between 293 and 674 (Table G7 in Technical Appendix G provides further details).

3.4.3.2 Results

The average peak traffic load ranges from 30,13 aircraft per hour for the most worked working position to 30,85 aircraft per hour for the least worked position. The medium worked position has with 29,28 aircraft per hour the lowest peak traffic load. These values are also depicted in Figure 33. For further details see Table G8 in Technical Appendix G.

The three age groups were compared regarding the mean peak traffic load per hour. Obviously, the peak traffic load differs depending on the kind of ATC service. This fact is taken into account further down in the report. For the time being, only the comparison of age groups throughout all services is of interest. Figure 32 below provides this comparison.

A one-way ANOVA was calculated to check for significant differences in the average peak traffic load between the three age groups. The analysis of variance identified significant differences in the mean peak traffic loads between age groups (for details see Table G9 in Technical Appendix G).

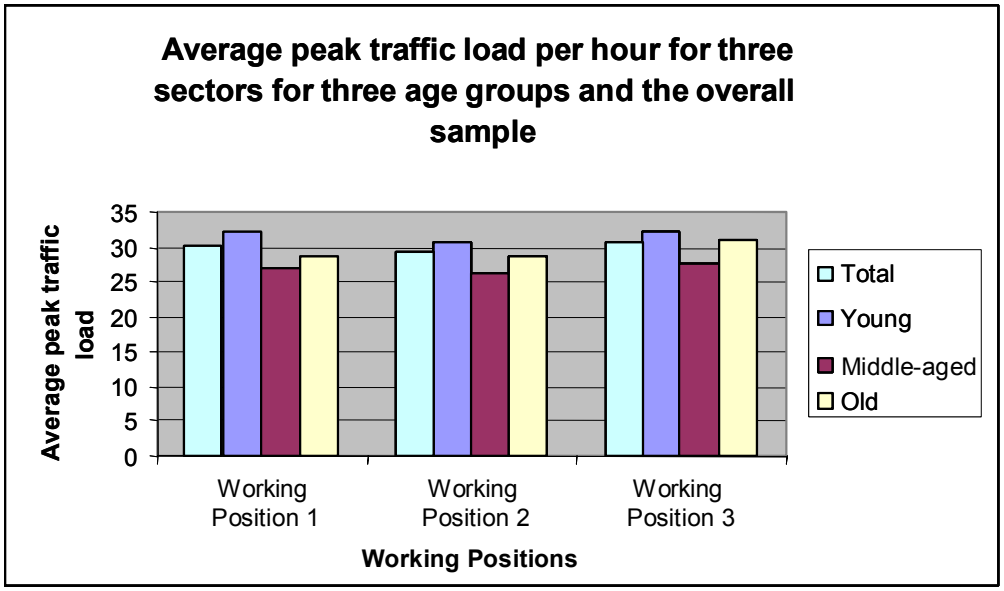

Figure 32: Average peak traffic load per hour for the three age groups and the overall sample for three working positions

The supplementary *post hoc* Tukey HSD tests for multiple comparisons revealed the following significant differences:

- For working position 1 (i.e. the most worked position) the means for the young and middle-aged groups, and for the young and old groups differ significantly. The young group has a peak traffic load per hour which is significantly higher than that of the middle-aged and old groups. The means of the old and middle-aged groups do not differ significantly.

- For working position 2 (i.e. the medium worked position) the means of the young and middle-aged groups differ significantly. The young group has a peak traffic load which is significantly higher than that of the middle-aged group. The means of the young and old groups, and of the middle-aged and old groups do not differ significantly.

- For working position 3 (i.e. the least worked position) the means of the young and middle-aged groups also differ significantly. The young group has a peak traffic load significantly higher than that of the middle-aged group. The means of the young and old groups, and of the middle-aged and old groups do not differ significantly.

The detailed results are provided in Table G10 in Technical Appendix G.

According to these results young controllers handle the highest amount of traffic per hour. Middle-aged and old controllers handle the same amount of traffic. This result is in agreement with the subjective self-assessment of the controllers described in Section 3.2.2. Old controllers believe that their ability to handle high traffic decreases. Interestingly, middle-aged controllers do not have the same perception of their traffic capacity, maybe because they are occupied with other non-operational tasks, which allows them to attribute their lower capacity to a lack of practice.

3.4.4 Context factors for job demand

Many of the context factors discussed above are very likely to have an impact on both subjective and objective job demand. For example, the indicators of objective job demand and peak traffic load per hour in a sector, and the indicators of subjective job demand and ratings on the four items on job demand differ in the various kinds of ATC services (see Tables G11 to G14 and Figures G1 and G2 in Technical Appendix G). However, this survey is not interested in these interactions as such, but rather in the relation with controllers' age.

The following interactions were tested, either with analysis of covariance or with an analysis of variance with two factors, but none of them achieved a significant result:

- impact of age and peak traffic load on subjective job demand: not significant (see also Table E84 in Technical Appendix E);

- impact of ATC service and age on subjective job demand: not significant (see also Table E84 in Technical Appendix E);

- impact of current function and age on subjective job demand: not significant (see also Table E84 in Technical Appendix E);
- impact of experience/time on current position and age on subjective job demand: not significant (see also Table E84 in Technical Appendix E);
- impact of prior experience in other ATC services and age on subjective job demand: not significant (see also Table E84 in Technical Appendix E);
- impact of prior experience in other ATC services and age on peak traffic load per hour: not significant (see also Table E84 in Technical Appendix E);
- impact of current function and age on peak traffic load per hour: not significant (see also Table E84 in Technical Appendix E);
- impact of time on current position and age on peak traffic load per hour: not significant (see also Table E84 in Technical Appendix E).

This lack of significant findings may be due to the same reasons as already outlined under Section 3.2.10 (heterogeneous sample, no strict experimental design). On the other hand, the fact that interactions with context factors could not be proven confirms the direct and strong impact of age on all indicators of job demand analysed in this survey.

3.4.5 Summary

- Subjective job demand: Generally, the mean ratings of all four aspects of job demand range between rather high and high. The data confirms a continuous increase in demand of night shifts with age. In addition, older controllers feel a higher general job demand and a higher demand during summer season. Daily peak traffic does not place a higher demand on older controllers. It is equally high demanding for all controllers.
- Peak traffic load per hour in a sector: Young controllers work the highest amount of traffic per hour. Middle-aged and old controllers work the same amount of traffic.

3.5 Ageing and Technological Change

3.5.1 Introduction

The driving force behind this survey is the increase of automation in European ATM. A number of characteristics of new technology offer a challenge for the ageing worker. Many human factors issues associated with the introduction of new technology, such as trust in automation, skill set changes, new error forms, changes in teamwork, situation awareness and

workload, are to be addressed for all age groups. It can be expected that these factors will be even more problematic for ageing employees.

Although ATCOs are well trained in adapting to changes, for instance in procedures, airspace structure, radio frequencies, etc., it cannot be assumed that the introduction of a new generation of automated technology will be easy to take for everybody. The objective of the human factors work is therefore to provide the support necessary for a successful and safe transition.

3.5.2 Technological change

3.5.2.1 Background

Research addressing the issue of older employees and technological change is primarily focused on the introduction of computer systems. These are the most widespread form of technology, affecting most professions in all areas of economy. Research conducted in France revealed that it is not necessarily the age which causes a negative attitude towards computers; it is rather the amount of experience one has with computers[11]. When people get the chance to gain experience with PCs, their attitudes become more positive, proportionally to the amount of experience gained.

Nevertheless, there are still some critical aspects regarding ageing and the introduction of computerised systems. The first one is the shift of incoming information to the visual channel. Information displayed on the screen replaces more and more other sources of data, e.g. auditory information via telephone. The concentration of data input on only one channel may easily cause an overload of working memory and lead to problems in the distribution of attention.

[11] For more details on the issue of ageing and automation see also EATMP (2003a).

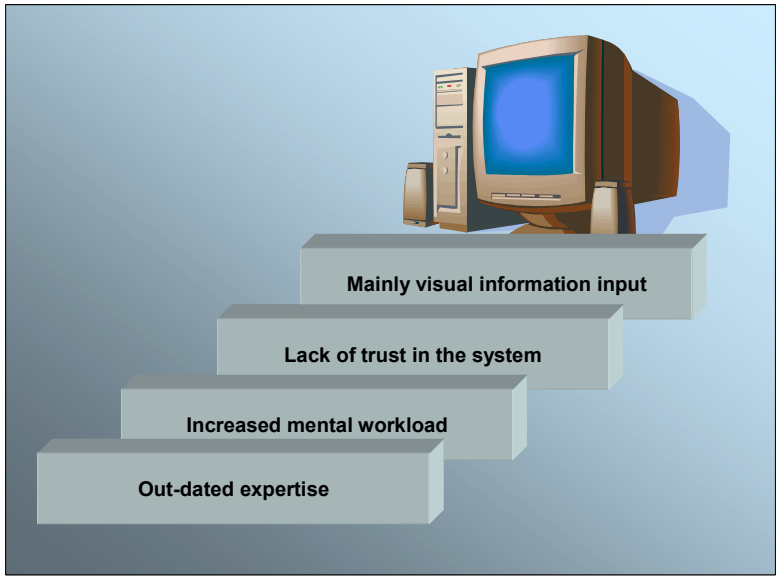

Figure 33: Steps to take on the way to successful system transition

Older controllers may 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 are 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 before one is able to diagnose a system failure or deviation. The acquisition of this theoretical information is more demanding for older people and might take a longer time 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. The period of 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. During this period a substantial amount of attention has to be allocated to handling the equipment; therefore less capacity is available for carrying out the usual job-related tasks. 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 as 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 older controllers. The rule that good design will support all controllers applies here as well. However, the older ones will benefit from it 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. If new equipment is introduced, not only changes might occur where professional knowledge is concerned, but there might also be drastic changes in working procedures. 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 former typewriters). Precisely for 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) might 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 air traffic control such a mechanism potentially causes dangerous situations.

There could also be positive aspects to this. System design can take the expertise of system operators into account. Involving older operators early in the design process could benefit the result of the design process. It could make easier the transition of expert knowledge from an old to a new system, helping operators of all age groups to handle the new system. Such an approach would comply with a basic rule of good design: good design for old age is helpful to all age groups. People of all ages would benefit from it, older users possibly a bit more than younger ones.

In the questionnaire (see Appendix) the ATCOs were asked whether they had experienced any technological upgrade in their equipment over the past five years. Furthermore, a tick list with equipment was proposed to specify the kind of technological change. This list included (the following) generic categories of equipment rather than individual pieces of equipment, because the number of suppliers and models of a certain element of technological equipment is too high to list all possible options:

- software upgrades of radar display (e.g. windows interface);
- automated aids for traffic planning (e.g. trajectory prediction tools);
- automated aids for conflict detection (e.g. Short-Term Conflict Alert [STCA]);
- additional information displays (e.g. for weather data);
- approach/departure support tools;

- automated support for airport surveillance;
- air-ground datalink; strip-less system;
- software upgrade in Flight Data Processing System (FDPS);
- hardware upgrades in FDPS;
- new input devices (e.g. mouse, keyboard, touch-screen, etc.).

An open question gave the possibility to supplement the list in case of any missing technological upgrade (see also Sections 2.1 and 2.2 in appended questionnaire).

In the following section the controllers were invited to give four examples of what was most helpful to them in terms of technological changes and four examples of what was most difficult for them (see also Sections 2.3 and 2.4 in appended questionnaire).

The assumption about age and technological change was that some older controllers might suffer from a certain resistance to the introduction of new equipment. They might try to avoid technological change, implying that they would have a lower frequency of technological changes. However, this is a hard-to-prove hypothesis, because technological change is almost unavoidable in operational work today. Moreover, those controllers who might not have been able to cope with new technology might have left the operational service, and therefore could not be the subjects of this survey. This question is yet worth being examined. A second assumption was that the age groups might differ as to the aspects of new technology, which are either helpful or difficult to cope with. This might also depend on the type of the technology that is introduced.

3.5.2.2 Results

Quantitative results

First, it was checked whether the three age groups differed with regard to their experience of technological change. Figure 34 shows the number of controllers in the three groups who have had a technological system upgrade in the past five years and those who have not. The data for the complete sample (i.e. the first two columns in the figure) shows that the majority of controllers have had such a system upgrade within the past five years: 844 (=78,22%) have and 213 (=19,74%) have not (see also Table H1, Technical Appendix H). These figures highlight how important the issue of technological change for the ATC community is, if almost 80% of the European controllers were confronted with such a step.

The data for the three age groups shows that throughout all ages there is a percentage of controllers who have not been faced with technological change within the past five years, even if most of them have.

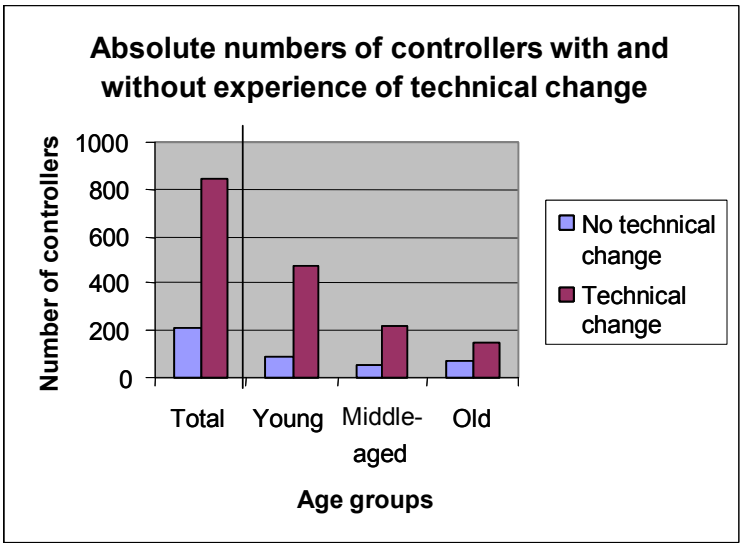

Figure 34: Absolute numbers of ATCOs who have been faced with technological change within the past five years

To get a clearer picture of the share of controllers with no technological change per age group the data was translated in percentages, which are provided in Figure 35 below. With 31,14%, the old group has by far the highest number of controllers who have not experienced technological change within the past five years. In the young group only 15,32% have not, and for the middle-aged group the percentage is 19,57.

A Chi^2-test revealed that there was a highly significant difference between the three age groups in the expected and observed frequencies of technological change (see Tables H2 and H3 in Technical Appendix H). In the young group there are significantly more controllers who have had a technological system upgrade and in the old group significantly less. This means that there are proportionally more old controllers who have not been faced with a system upgrade within the past five years. This result confirms the initially formulated hypothesis that older controllers are more likely to avoid technological change, even if it remains unclear how they manage to do so.

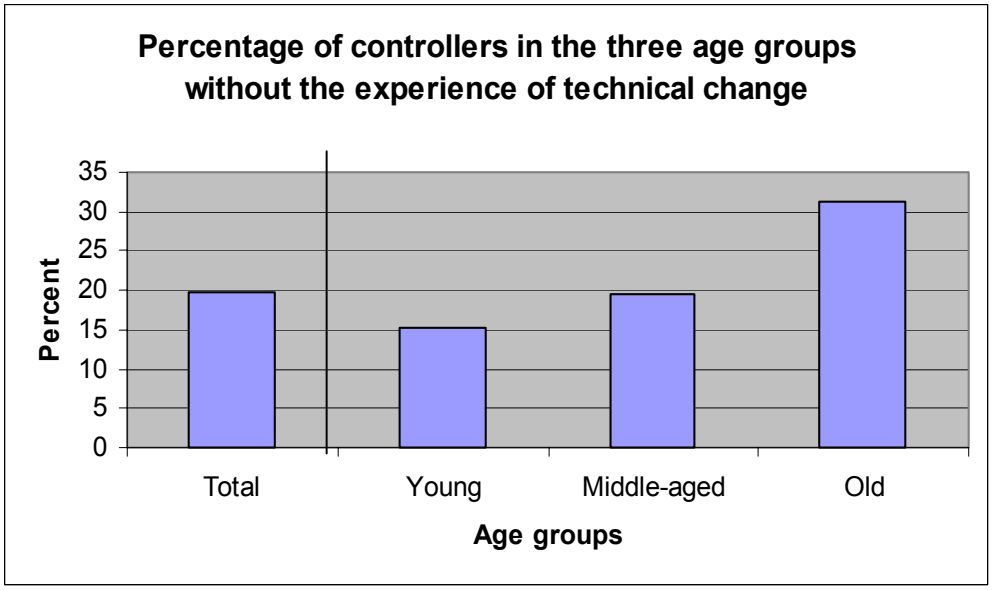

Figure 35: Percentage of controllers in the overall sample and the three age groups which have not had any technological change within the past five years

As a second step it was checked, with the aim of comparing the results, whether the age groups differed as to the kind of equipment upgrade[12].

Figure 36 below depicts the frequencies for the overall sample and the three age groups.

The most frequent area of change concerns radar hardware and software. The second largest category of technological change is FDPS software, followed by new input devices (e.g. mouse or touch screen) and additional information displays. New planning tools (e.g. trajectory prediction tools), hardware upgrades of the FDPS and the introduction of conflict detection tools (like STCA) are also rather frequent. Less frequent are the introduction of approach/departure support tools, datalink or strip-less systems and airport surveillance support tools, maybe because of the status of technological development in these three areas. The low number of airport and approach/departure tools is not due to a lack of controllers in these services since the number of ACC and TWR or APP controllers is well balanced in the sample (see Section 3.2.2, 'Kind of ATC service').

[12] The following categories were proposed to the participating controllers: Software upgrades of radar display (e.g. windows interface); Automated aids for traffic planning (e.g. trajectory prediction tools); Automated aids for conflict detection (e.g. STCA); Additional information displays (e.g. weather data); Approach/departure support tools; Automated support for airport surveillance; Air-ground datalink; strip-less system; Software upgrade in FDPS; Hardware upgrades in FDPS; and New input devices (e.g. mouse, keyboard, touch screen, etc.).

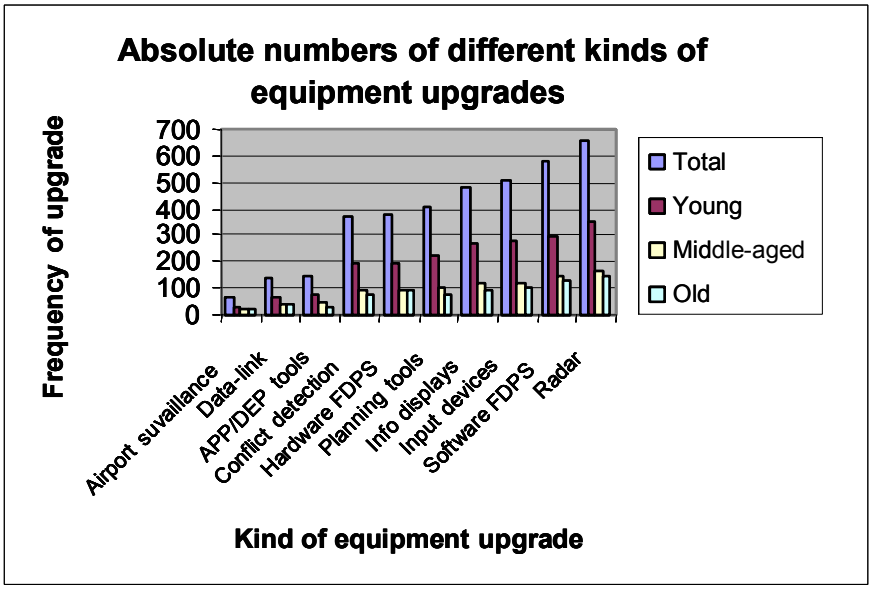

Figure 36: Frequencies of kinds of technological change for the overall sample and the three age groups

A Chi^2-test revealed only one significant difference – datalink - between the expected and observed frequencies for the three age groups (see Tables H4 to H23 in Technical Appendix H). Significantly more controllers in the old group than in the young one have experienced the introduction of datalink (see Tables H16 and H17 in Technical Appendix H). However, this result should be interpreted with care; it may be due to a biased age structure in the few units having already introduced datalink.

In general it is not surprising that there is no difference as to the kind of technological change between the age groups. As soon as the decision is taken to implement a new system operational controllers have no choice but to pick up certain elements from the upgrade programme only and leave others. Whether there are differences between the three age groups in how intensively, frequently and efficiently a tool is used by controllers cannot be answered from the available data.

Another question of interest was whether the subjective job demand would change with the introduction of a new technological system. Figure 37 shows the results. For all four categories of subjective job demand (demand of job in general, demand of peak traffic, demand of summer season and demand of night shift) the mean ratings are slightly lower for the group of controllers which have had a technological change.

Mann-Whitney U-tests revealed that there is indeed a significant difference in the mean ratings between the two groups (with and without technological change) for two items on job demand (see also Table H24 in Technical Appendix H). Both the job in general and the night shifts in particular are perceived significantly less demanding by those controllers who have had a technological system upgrade within the past five years.

Whether there are any specific effects with regard to the age of the controllers is discussed further down in this section.

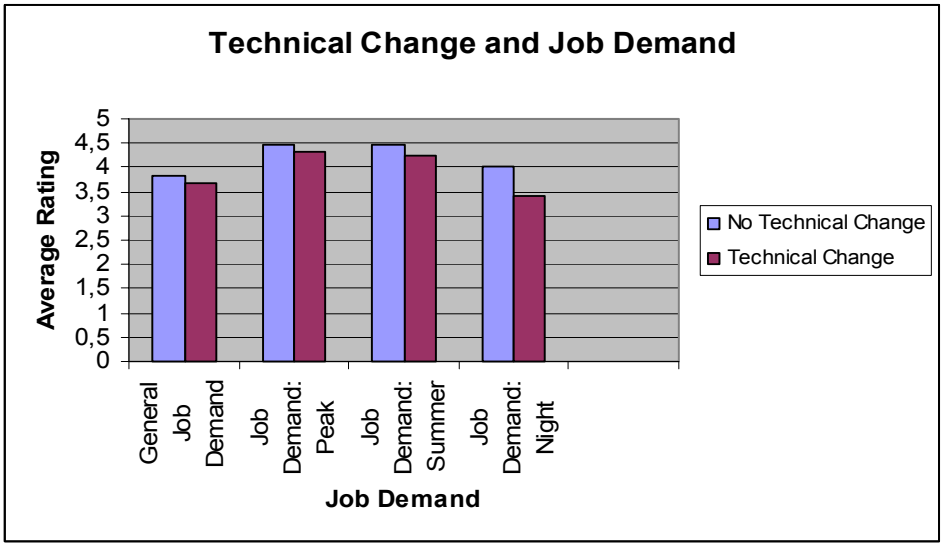

Figure 37: Technological change and subjective job demand

Equally interesting is the question whether the objective job demand (peak traffic load per hour) changes according to technological change. Figure 38 presents the mean traffic load per hour for controllers with experience of technological change within the past five years and for those without such experience. The age of the controllers is not taken into account in this figure.

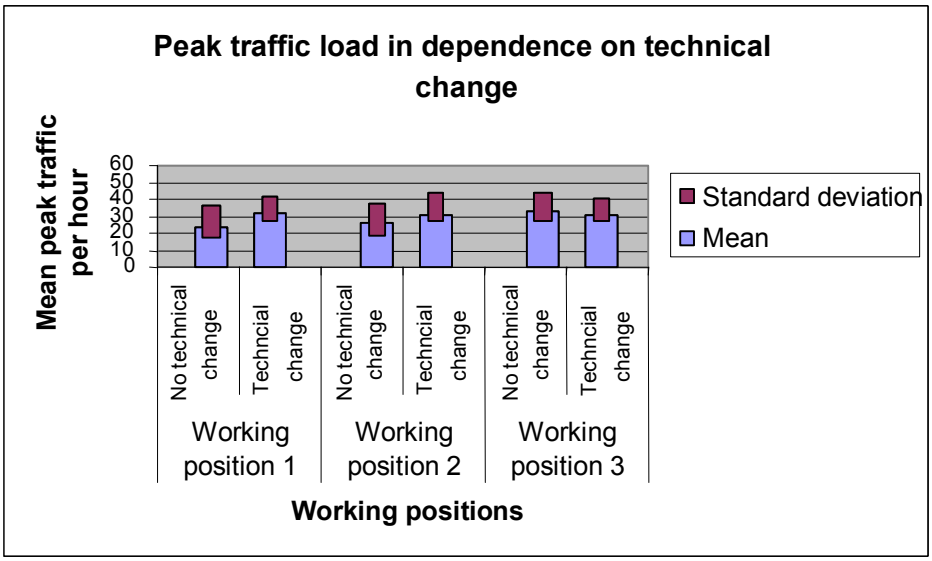

Figure 38: Peak traffic load per hour on three working positions in dependence of technological change

The figure shows that the peak traffic load (peak number of aircraft per hour) on working positions 1 and 2 is clearly higher under the condition of technological change. For position 3 it is slightly lower with technological change. Table 15 below summarises the mean traffic load per hour for the three positions both for technological change and for no technological change.

Table 15: Mean traffic load per hour for three working positions in dependence of technological change

Mean traffic load per hour		
Working position	**No technological change**	**Technological change**
Working position 1	23,9931	31,5498
Working position 2	25,4479	30,8740
Working position 3	32,7857	30,4164

ANOVAS was used to calculate the difference in the mean traffic load in both contexts (technological change and no technological change). It revealed that for working positions 1 and 2 the difference is indeed significant. Controllers who have had a technological upgrade within the past five years handle more traffic. For working position 3 the difference did not become significant (see also Tables H25 to H30 in Technical Appendix H). Subsequent Tukey HSD tests were not necessary in this case, because only two groups needed to be compared. Therefore, the significant ANOVA results automatically prove a significant difference between these two groups.

Qualitative results

The questionnaire gave the possibility to qualitatively assess the technological system upgrades by asking two open questions on this issue: the first one was 'What were the most helpful aspects of this upgrade for you?', and the second one was 'What were the most difficult aspects of this upgrade for you?' (see also the questionnaire Sections 2.3 and 2.4 in the Appendix).

All statements were taken into account for the evaluation. They were summarised separately for helpful and difficult aspects. As this data is purely qualitative no inferential statistical evaluation was conducted. Consequently, no hypothesis on the outcome of the two open questions could be ventured. However, the descriptive approach to the data is still very useful and supplies interesting insights into the topic.

887 statements addressing helpful aspects of the technological upgrade experienced during the last five years were made. The young group provided 498 comments, the middle-aged group 215 and the old group 174. This unequal distribution of comments over the three age groups is mainly due to

the unequal group sizes (there are 568 controllers in the young group, 281 in the middle-aged one and 228 in the old group).

Table 16 below provides the ratio of comments per controller in the three groups. Generally, the controllers made more comments on the helpful aspects: 887 statements addressed the positive and helpful aspects of the system upgrade, while 405 statements referred to the negative and difficult aspects of it.

Table 16: Ratio of number of controllers and frequencies of statements per age group

Type of age group	N	Number of controllers who made positive statements	Number of positive statements	Number of controllers who made negative statements	Number of negative statements
Young	568	374	498 1,33 per controller	163	189 1,16 per controller
Middle-aged	281	164	215 1,31 per controller	92	120 1,30 per controller
Old	228	133	174 1,31 per controller	77	96 1,25 per controller
Total	**1079***	**671**	**887** **1,32 per controller**	**332**	**405** **1,22 per controller**

* Two questionnaires out of the total of 1079 had to be excluded because they did not include information on the controller's age. However, this total does not reflect the removal of the two corresponding replies.

The ratio (i.e. the number of controllers per age group divided by the number of statements per age group) is 1,32 for the helpful aspects and 1,22 for the difficult aspects. The comparison of the three age groups shows no difference for the helpful aspects and only slight deviations for the difficult aspects. Regarding the helpful aspects the ratio is almost equal for the three groups, i.e. 1,33 statements per controller for the young group, and 1,31 for both the middle-aged group and the old group. The statements on difficult aspects show slight deviations for the three groups: the young group has the lowest number of negative comments per controller (1,16) and is followed by the old group with a ratio of 1,25. The record number of negative statements per controller is held by the middle-aged group with a ratio of 1,30.

In this context it is also of interest to look at the ratio of positive and negative comments within one single age group. Table 17 shows that there are more

controllers who provided positive comments in the young group than in the other two groups: of the 568 ATCOs in the young group 374 (65,85%) indeed made positive statements and 163 (28,70%) provided negative statements[13], while for the other two groups the ratio is slightly more shifted towards the negative side, with approximately 58,3% of controllers having made positive comments and 32% to 33% having made negative statements.

Table 17: Percentage of controllers who gave positive or negative comments

Type of age group	N	Number of controllers who made positive statements	Percentage	Number of controllers who made negative statements	Percentage
Young	568	374	65,85	163	28,70
Middle-aged	281	164	58,36	92	32,74
Old	228	133	58,33	77	33,77
Total	**1079***	**671**	**62,19**	**332**	**30,77**

* Two questionnaires out of the total of 1079 had to be excluded because they did not include information on the controller's age. However, this total does not reflect the removal of the two corresponding replies..

Helpful aspects

Further in the evaluation process the statements were grouped into categories using the similarity of statements as criteria. For example, all statements dealing with the advantages of a new radar system ended up in the same category. 22 categories were identified using this method. The categories and corresponding frequencies of statements per age group are listed in Table 18.

[13] Positive statements refer to the helpful aspects of system change, while negative statements address the difficult aspects of the new system.

Table 18: Summary of the helpful aspects of technological change

Category of helpful aspects of technological change	Frequencies of statements per category for each age group			
	Total	**Young**	**Middle-aged**	**Old**
Helpful system elements (software and hardware)	689	380	173	136
Radar – hardware and software aspects	150	68	41	41
Additional information – availability and displays	91	60	22	9
FDPS	85	40	26	19
Traffic planning tools	82	53	16	13
Electronic strips / datalink	68	44	11	13
STCA	67	32	20	15
Approach/departure and airport support tools	53	31	16	6
General software issues	33	23	5	5
R/T communication	23	15	6	2
Data input	23	5	10	8
General hardware issues	9	9	-	-
General system improvement	5	-	-	5
Positive consequences of new system	114	76	22	16
Easier working	46	21	15	10
Workload reduction	18	18	-	6
Time saving / speed	20	13	7	-
Safety	10	10	-	-
Reliability	7	7	-	-
Capacity	7	7	-	-
General comments	35	22	6	7
Everything is helpful	21	10	4	7
Nothing is helpful	9	7	2	-
Indecisive	5	5	-	-
Rest	49	20	14	15
Others (rest category)	49	20	14	15
Total	**887**	**498**	**215**	**174**

The following four groups of categories could be identified (grey shaded in the table): 'helpful system elements (hardware and software)', 'positive consequences of new system', 'general comments' and 'rest'. The 'rest' category contains all statements which did not fit in any of the other categories and were too few to build other categories of their own.

The first group, 'helpful system elements (hardware and software)', contains all categories dealing with helpful hardware or software elements of the new system. Most frequent were the statements addressing the new radar system. The second largest category of appreciated elements includes additional information displays, and the third lone deals with FDPS. Traffic planning tools, electronic flight strip systems and conflict detection tools were also regarded as helpful by many controllers. Approach and airport control support tools received many positive statements too. Less frequently cited were the general software issues, the comments addressing R/T communication, the general hardware issues and the comments stating a general system improvement. However, the value of these statements must not be underestimated; it is remarkable that they were made knowing that, in an open question, only issues felt as really important are addressed. The detailed list of statements for each category can be found in Technical Appendix H, Tables H31 to H33.

The second group of categories deals with the positive consequences of the system upgrades. In this group most of the statements reveal that work is perceived easier using the new system. Comments confessing a reduction in workload are in second position, followed by statements that the new system helps to save time. It is to be noted – and this is remarkable - that the time saving aspect was not pointed out at all by the old group. Equally, the categories of system 'safety', 'reliability' and increased 'capacity' are only filled with comments made by the middle-aged and young groups. Although it is impossible to do a statistical test for significance with this qualitative data, this is an interesting finding, in that it confirms the often-stated lack of trust in new systems, especially by older controllers.

The group with 'general comments' contains the categories 'everything is helpful', 'nothing is helpful' and 'indecisive'. The last category contains statements like 'don't know', 'can't tell', etc. Luckily only very few controllers are in this category. There are more controllers who find that everything of the system upgrade is helpful (21 comments) than the contrary (nothing helpful: nine comments).

Difficult aspects

Applying the same method (that is grouping according to similarity of statements) to the statements about difficult system aspects resulted in nineteen categories.

Table 19 provides the categories and corresponding frequencies of statements per age group. They are also summarised under headings parallel to the headings for the helpful aspects. The four resulting groups are

'difficult system elements (software and hardware)', 'consequences and side effects of system implementation', 'general comments' and 'rest'. The detailed list of statements per category can be found in Technical Appendix H, Tables H34 to H36.

Table 19: Summary of the difficult aspects of technological change

Category of difficult aspects of technological change	Frequencies of statements per category for each age group			
	Total	**Young**	**Middle-aged**	**Old**
Difficult system elements (software and hardware)	165	80	41	44
Radar – hardware and software aspects	59	27	14	18
Data input	36	17	10	9
FDPS	22	7	7	8
Aids for traffic planning	11	11	-	-
Datalink	11	4	3	4
Software problems	9	4	5	-
R/T communication	4	4	-	2
Compatibility of systems	5	3	2	-
Interface problems	3	3	-	-
STCA	3	-	-	3
Negative consequences and side effects of system implementation	156	66	59	31
Technical problems, bugs, system failure	42	24	9	9
Learning and adapting to the new system	36	17	11	8
Poor training	29	15	9	5
Ergonomic problems	24	-	18	6
Amount of change	10	-	10	-
Information overload	10	5	2	3
Adaptation of system to the operator	5	5	-	-
General comments	25	17	3	5
No difficulties	25	17	3	5
Rest	59	26	17	16
Others (Rest category)	59	26	17	16
Total	**405**	**189**	**120**	**96**

The first group dealing with software and hardware elements of the new systems contains ten categories. Like for the helpful aspects, the category

with the most statements refers to radar systems. This high number of statements, both in positive and negative directions, may be due to the fact that radar is an essential tool for ATCOs, therefore drawing their attention more particularly. The second largest category include comments on the difficulty of data input. It is followed by that with statements on FDPS. Equally often mentioned as being difficult are aids for traffic planning and datalink. General software problems is the next category, and R/T communication and compatibility of systems are less frequent. Interface problems and STCA are the categories including the least statements.

The second group deals with the consequences and side effects of the new technology. The top category, that is with the most statements, addresses system failures, bugs and other technical problems. Undoubtedly, these factors are difficult for controllers to deal with, especially if technical problems occur when the system is already online and supposed to work properly. The second category deals with learning and adapting to the new system. Interestingly, not only the middle-aged and old controllers are of the opinion that the new system requires a high effort in learning and adapting to them. Poor training was also a frequent concern. This aspect will be discussed in further detail in the next section. The category 'ergonomic problems' is as well rather frequent but interestingly only the middle-aged and old controllers made comments in this context. Apparently, it shows that the ageing body is less tolerant to working conditions which are not optimised from an ergonomic point of view. This ranges from lighting conditions to location of information sources or twisted sitting positions. The next category, 'amount of change', includes statements which were made only by the middle-aged controllers. This is a surprising fact, as one would rather expect that old controllers suffer most from the amount of new information. In Section 3.3.2 on the perception by ATCOs of the ageing process and experience, it was mentioned that older controllers agree more strongly to the statement 'learning gets more difficult for me'. Complaints about information overload are rather infrequent. This is in line with the finding that additional information displays are amongst the most appreciated elements of the system upgrades (see 'helpful aspects' above). The least frequent comments concern the adaptation of the system to the operator, for example to make the system comply with the own intentions. Interestingly, all the statements in this category are provided by young controllers. Possibly they have higher expectations on system usability because most of them are more familiar with computerised systems.

The group of general comments contains only one category. Many controllers did not have any problem using the new system and found this fact was worth stating.

Some of the statements regarding the difficult side of system transition could be related to a number of concerns formulated at the beginning of this sub-section. 42 controllers stated that technical problems, bugs and system failure are difficult for them. Also, many aspects associated with learning provide a challenge to the controllers. 36 mentioned learning and adapting to the new system as difficulty. Poor training is a worry for 29 controllers. The amount of change they have to face and the information overload are

problematic for twenty of them. These results back up certain concerns formulated above. Especially the high demand of learning and related issues seems to be an issue deserving special attention. Moreover, the worrying possibility of system failure should be carefully taken into account by system developers and when conceiving transition training.

The interested reader may have a look at Tables H31 to H36 in Technical Appendix H, containing the lists of all the statements provided by the ATCOs in the questionnaires. Some comments are highly worthy of note, especially if one is interested in the assessment of a certain piece of equipment. This information is that detailed it could not be included in this report, as otherwise it would have been beyond the scope of it.

3.5.3 Transition training

3.5.3.1 Background

One of the most robust findings of ageing research is the phenomenon that older people find it harder to learn something new. This fact may well influence the reluctance of older people to deal with new technology. The objective of many research projects in this area is to teach computer skills to older adults who are not yet computer-literate. Individuals who have not had a chance to gain experience with computers often have to overcome a barrier before they are able to have a first contact with them.

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 the training is delivered need to be adapted to the target group. To adults the contents must make sense; they are not willing to learn theoretical material 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 practise the new skill extensively, and if they can learn at their own pace and without pressure. It also turns out to be of benefit if the teacher is the same age than trainees.

A special difficulty in computer usage by older people is the use of the mouse as an input device[14]. 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 older users. A simple design solution would be to avoid double-clicking functions.

In the context of ATM the difficulty to learn new things might be translated as difficulties to train for a new technological system. This is why the questionnaire included a section on transition training intended to find out the ways to support and make the transition training easier (see also Section 3 in appended questionnaire).

[14] Smith, Sharit & Czaja (1999)

The questions on transition training consisted of the following statements, associated with a six-point rating scale from 'very much disagree' to 'very much agree', on which the controllers were asked to tick the option best corresponding to their perception:

- prior experience with computers (e.g. PC at home) helps me in the transition to a new system;
- it confuses me when our training simulator has bugs (technical problems) in the new system it is simulating;
- being personally involved in the system development makes it easier for me to make the transition;
- Computer-based Training (CBT) tools are helpful to me to become familiar with the new system;
- the amount of information I have to learn places a high demand on me;
- I would prefer to have more training time for the transition training;
- I would prefer a flexible adaptation of the training time to individual requirements.

These statements were retrieved from the outcome of the interview survey conducted with 76 European controllers by DIS/HUM in Spring 2001.

The objective of the evaluation of these statements was twofold:

- on the one hand it was aimed at seeking general confirmation for the statements, with a view to formulating recommendations for transition training;
- on the other hand a comparison between the answering behaviours of the different age groups might provide hints towards an adaptation of the training design to the needs of older controllers.

3.5.3.2 Results

The mean ratings per item are depicted in Figure 39. The graph shows the mean ratings separately for the three age groups and the overall sample. The overall agreement to the seven items is rather high. A rating value of 4 equals the verbal statement 'somewhat agree' and 5 equals 'agree'.

The overall sample shows the highest agreement for item 1 ('prior experience with computers (e.g. PC at home) helps me in the transition to a new system') and item 4 ('Computer-based Training (CBT) tools are helpful to me to become familiar with the new system'), both with a rating value of 4,76. Item 7 ('I would prefer a flexible adaptation of the training time to individual requirements') achieved with a value of 4,60 the next highest

rating. Item 3 ('being personally involved in the system development makes it easier for me to make the transition') reached a value of 4,48 and item 6 ('I would prefer to have more training time for the transition training') a value of 4,22 on the rating scale. The two items with the lowest agreement are item 2 ('it confuses me when our training simulator has bugs (technical problems) in the new system it is simulating') with 3,89 and item 5 ('the amount of information I have to learn places a high demand on me') with 3,87. However, both items are still on the agreement side of the rating scale. For more details on the figures see Table H37 in Technical Appendix H.

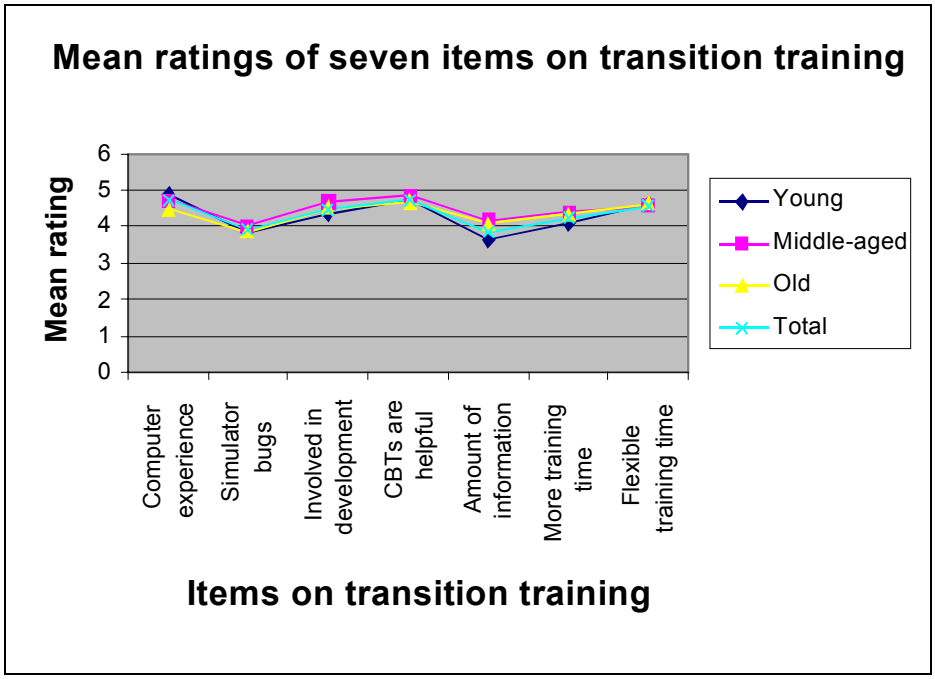

Figure 39: Mean ratings of seven items on transition training for the three age groups and the overall sample

Figure 39 also shows the deviations in the ratings between the three age groups. Generally, the groups have rather similar mean ratings. Only for item 1 on prior computer experience and item 5 on the demand of the amount of information to learn there are clear deviations. Slight deviations are visible for item 3 on involvement in system development and for item 6 on more training time.

A Kruskal-Wallis test for k independent samples was applied to test the data for significant differences in the mean ratings. Only for three items highly significant differences (α=1%) appear: for item 1 (prior computer experience), for item 5 (high demand of amount of information) and for item 6 (more training time). Item 3 (involvement in system development) shows a significant difference on the 5% level. For details see Table H38 in Technical Appendix H.

The comparison of the three age groups with one another applying supplementary Mann-Whitney U-Tests revealed differences between the groups (for details see Tables H39 to H41 in Technical Appendix H), which are summarised in Table 20 below.

Table 20: Significant differences between the three age groups (21 to 36, 37 to 47, and 48 to sixty years) regarding their rating of items 1 to 7 on transition training

Significant differences between the age groups*	Items on transition training
The young and middle-aged groups agree more strongly to this statement than the old group.	Prior experience with computers (e.g. PC at home) helps me in the transition to a new system.
The middle-aged group agrees more strongly to this statement than the young group.	Being personally involved in the system development makes it easier for me to make the transition.
The middle-aged and old groups agree more strongly to these statements than the young group.	The amount of information I have to learn places a high demand on me. I would prefer to have more training time for the transition training.

* The corresponding exact figures can be found in Table H42 in Technical Appendix H.

No significant difference could be found for the remaining three items.

The differences between the age groups are in line with the results about cognitive changes. Older and middle-aged controllers perceive the amount of information they have to learn more demanding and would appreciate a longer training time. At the same time old controllers benefit less from prior experience with computers than the other two groups. The high agreement of the middle-aged group to the statement 'being personally involved in the system development makes it easier for me to make the transition' may be due to the fact that this group is indeed most likely to be involved in technical projects dealing with new system developments.

3.5.4 Context factors for technological change

The process of a technological system upgrade is not an isolated event; it is embedded in the day-to-day ATC environment. All the context factors outlined in Section 3.2 are present and may have an influence on the success of system transition. In this section the impact of a number of these context factors on technological change, in interaction with the age of controllers, is tested.

The link between technological change and job demand has already been analysed in Section 3.5.2 above. However, no other interaction with the age of controllers could be found.

The following interactions were tested with analysis of covariance or with an analysis of variance with two factors, but none of them achieved a significant result:

- impact of kind of ATC service and technological change on age: not significant (see also Table H43 in Technical Appendix H);
- impact of current function and technological change on age: not significant (see also Table H44 in Technical Appendix H);
- impact of technological change and age on peak traffic load per hour: not significant (see also Table E84 in Technical Appendix E);
- impact of age and technological change on time on current position: not significant (see also Table E84 in Technical Appendix E);
- impact of technological change, age and peak traffic load on subjective job demand: not significant (see also Table E84 in Technical Appendix E).

Again, the results are rather disappointing, maybe because the process of technological change as such already includes a high amount of 'error variance'. The term 'technological change' not only covers all the pieces of equipment due for upgrade, but also the different processes to do these upgrades, the ways of conducting the transition training, and so on.

3.5.5 Summary

Technological change

- The results confirm that older controllers are more likely to avoid technological change. Proportionally less older than middle-aged or young controllers have experienced a technological system upgrade within the past five years.
- Regarding the different kinds of technological upgrade no difference between the age groups is recognisable.
- Both the job in general and the night shifts in particular are significantly less demanding for those controllers who have had a technological system upgrade within the past five years.
- Controllers who have had a technological upgrade within the past five years handle more traffic.

- The controllers made more comments on the helpful aspects of the introduction of a new system: 887 statements addressed the positive and helpful side, while 405 statements referred to the negative and difficult aspects. The young controllers made more positive statements.

- Many comments referring to the difficult aspects of technological change confirm the concerns formulated at the beginning of this section.

Transition training

- Older and middle-aged controllers perceive the amount of information they have to learn as more demanding, and they would appreciate a longer training time. At the same time old controllers benefit less from prior experience with computers than the other two groups. Many middle-aged controllers appreciate the personal involvement in system development.

4. KEY ELEMENT IDENTIFICATION

4.1 Introduction

This section provides the synthesis of the work done so far in the area of ATC and ageing. Both the results from the questionnaire evaluation and those from the literature review are applied to the controller's skill set identified by the SHAPE Project. This list of controller's cognitive skills contains 21 items which are further broken down into basic cognitive elements of the controller's task. With the support of the results from the questionnaire and other research it is possible to recognize for each of the elements whether they will be transformed in dependence of ageing or whether they will remain unchanged. This process of identification takes into account both the declines due to age and the gains due to experience. For each cognitive element the positive and negative impacts are weighed up. Depending on the overall score it is decided whether the skill is more likely to decline or improve with increased age.

The approach to the question of the key element identification is depicted in Figure 40 below.

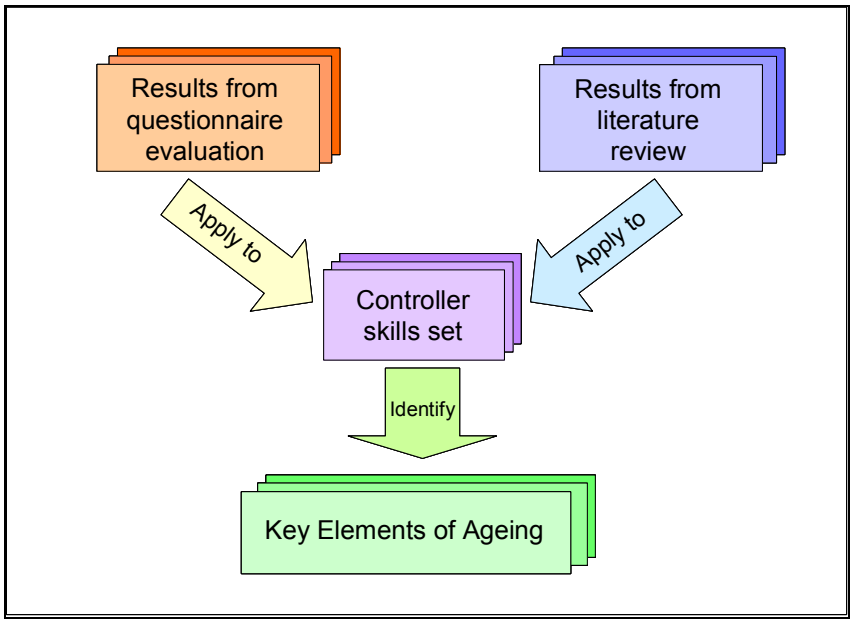

Figure 40: Approach within the identification of key elements of ageing

In Section 4.2 the results from literature review are summarised.

In Section 4.3 the results from the questionnaire evaluation are described in a few words.

Section 4.4 makes use of the cognitive skill list and concludes on the changes of these skills due to age and experience.

In Section 4.5 key elements are named according to their importance in the overall ATM environment.

The resulting list of gaining and declining cognitive skills will serve as basis for the development of scenarios to tackle the issue of ageing in ATM (see Section 5).

4.2 Summary of Results of Literature Review

This section gives a condensed summary of the effects of ageing discussed in scientific literature. An elaborate description of these processes, and their meaning for ATM, are available in EATM (2003a).

For this summary the impacts of ageing documented in literature are grouped in the following two broad areas: cognitive skills changes and changes in job performance.

4.2.1 Cognitive skills changes

Declines with age

- Vision gets worse.
- Hearing gets worse for some individuals.
- Overall attention gets worse.
- Selective attention seems to get worse.
- Sustained attention gets worse.
- Demanding data processing gets worse.
- With ageing working memory suffers from a decrease in information processing speed.
- 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 the learner's characteristics.
- Spatial reasoning (e.g. perspective taking, mental rotation of objects, spatial memory and environmental learning) gets slower and less accurate with increased age.

- In unfamiliar domains older people display a decreased efficiency in problem solving, especially if problems are complex.

No changes

- Automated information processing remains the same.
- Divided attention seems to remain the same.
- Short-term memory is hardly impaired by ageing.
- In familiar domains there is hardly any impairment of problem solving, efficiency and quality due to increased age.

Gains due to experience

Some of the cognitive skills remaining unchanged with age may even show an improvement for employees who have reached a level of expertise in their job:

- Automated information processing improves (highly trained tasks are carried out automatically with no need for much conscious attention).
- Broad knowledge about the subject is acquired (structured, principled knowledge).
- Useful rules on what to do, how to do it and when to do what are stored in memory (proceduralised knowledge).
- Rapid and accurate strategies are used to improve short-term memory by making use of the long-term memory (skilled memory).
- Problem representation becomes more effective (experts spend extensive time on analysing the problem and by doing so increase the chance of solving it).
- Strong self-regulatory skills develop (that is experts monitor their problem solving by predicting the difficulty of a problem, allocating time appropriately, noting their errors or failures and checking possible solutions).

4.2.2 Changes in job performance

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

- 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.
- Some studies conducted with air traffic controllers in the United States pointed out a negative relationship between age and job performance. Performance seems to decline as controllers get older.
- Job performance can be broken down into components, some of which decrease with ageing, some of which increase and some of which remain the same.

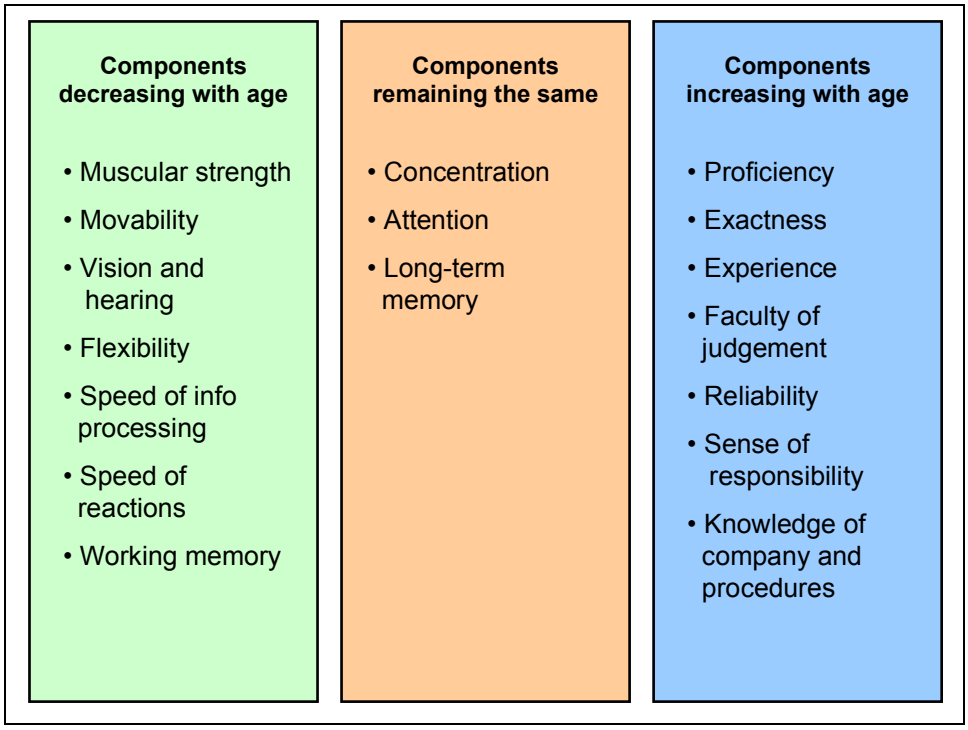

Figure 41: The impact of ageing on components of job performance

4.3 Summary of Questionnaire Results

The questionnaire results have already been summarised at the end of Sections 3.2 to 3.5. They are repeated condensed and simplified as a reminder in Table 21.

Table 21: Condensed summary of questionnaire results

Context Factors	Kind of ATC service: The controller's mean age varies from service to service.
	Current function: Older controllers work more in combinations of functions involving supervisory tasks. Young controllers are more often radar controllers and less often planning controllers, and the middle-aged group works more in combinations involving planning control.
	Other tasks/duties: Old controllers spend more time on other duties; the kinds of other duty vary between the three age groups.
	Overall job experience and experience on current position: The older the controllers, the higher are the overall job experience and the experience on current position.
	Prior experience in other ATC services: The older the controllers the longer is the time in other ATC services.
	Part-time work: Young and old controllers do more part-time work, but of varying intensity.
	Number of validations: Is the same for the three age groups.
	Other influencing factors: All controllers agree to the importance of the influencing factors 'work on radar position, 'high traffic load', 'doing part-time work' and 'motivation'.
	Interactions between the context factors: Those middle-aged and old controllers who have some experience in other ATC services have a slightly shorter experience on their current working position.
Cognitive Ageing – Gains of Experience	Ageing processes and experience: With increasing age controllers feel the negative impacts of ageing more strongly. All controllers show agreement to the positive experience-related items.
	Gains due to experience: Middle-aged and old controllers agree that they become better at a number of tasks, while young controllers do not find that their older colleagues become better.
	Onset of ageing: Middle-aged and old controllers feel the compensating power of experience more strongly. Older controllers perceive ageing more positively than younger controllers. Older controllers rate the start of ageing later than younger controllers do (on average at 44,83 years)
Job Demand and Strain	Subjective job demand: Older controllers feel that the job in general and the summer season and night shifts in particular are more demanding.
	Peak traffic load per hour: Young controllers handle the highest amount of traffic per hour. Middle-aged and old controllers handle the same amount of traffic.

Table 21: Condensed summary of questionnaire results *(continued)*

Ageing and Technological Change	Technological upgrade: Proportionally less older controllers than middle-aged or young controllers have experienced a technological system upgrade within the past five years.
	Kinds of technological upgrade: Regarding the different kinds of technological upgrade no difference between the age groups is recognisable.
	Night shifts and technological upgrade: Both the job in general and the night shifts in particular are significantly less demanding for those controllers who have had a technological system upgrade within the past five years.
	Traffic handling and technological upgrade: Controllers who have had a technological upgrade within the past five years handle more traffic.
	Trust and technological upgrade: The controllers made more comments on the helpful aspects of the introduction of a new system. The young controllers made more positive statements.
	Transition training: Older and middle-aged controllers perceive the amount of information to learn as more demanding, and would appreciate a longer training time. At the same time old controllers benefit less from prior experience with computers than the other two groups. Many middle-aged controllers appreciate the personal involvement in system development.

4.4 Controllers' Cognitive Skill Set

In this section the controllers' cognitive skills are analysed in terms of the impact of ageing and experience. The skills, each of which is further broken down into sub-elements, are listed below. An assessment whether the skill will improve thanks to experience or decline because of ageing is provided. Both for ageing and experience a two-step scale is used to weigh their impact on each skill: for a negative impact of ageing a minus sign (-) is used, while for a positive impact of experience a plus sign (+) is used. The number of signs indicates the strength of the impact. Table 22 below details the meaning of the signs. When, for some cognitive elements, the impact cannot be determined clearly, a question mark is entered in the corresponding row.

Table 22: Signs used for the assessment of the impact of ageing and experience on cognitive skills

Sign	Meaning
(-)	Low negative impact of ageing
(- -)	High negative impact of ageing
(+)	Low positive impact of experience
(+ +)	High positive impact of experience
(?)	Nature of impact cannot be determined

For each cognitive skill two columns are provided, one for the gains and another for the declines, as both processes can be effective for the same skill. In addition to the evaluation of the strength and the direction of the impact, short explanations on each assessment are provided.

The following 21 cognitive skills were identified by the SHAPE Project Team:

1. Multitasking.
2. Direct attention to information source.
3. Take account of and process external information (from radar, new Flight Progress Strip (FPS), coordination, pilot requests).
4. Monitoring.
5. Manage working memory.
6. Integrate into long-term memory.
7. Build up mental picture of traffic situation.
8. Develop a plan.
9. Maintain situational awareness.
10. Active planning.
11. Make decision for control actions.
12. Solve aircraft conflict.
13. Manage requests and assist pilots.
14. Diagnose perceived problem.
15. Active problem solving.
16. Diagnose novel situations/problems.
17. Awareness of team situation.
18. Team multitasking.
19. Team working.
20. Share mental picture of traffic situation during handover.
21. Establish mental picture of situation during takeover.

The above-listed skills are rather complex, consisting of much more than the basic cognitive functions usually tested in research on cognitive ageing. Therefore, none of these skills are purely either positive or negative. All of them show both some declines due to ageing and some gains by experience. This fact made the assessment of the skills more complicated and required an approach which allowed to take the two possible effects into account. This is why an assessment on both the positive and negative impacts, resulting respectively in gains and declines, is provided.

Generally it is more difficult to apply the positive, experience-related gains to the cognitive skill list. For the decline side of mental processing, research has reached a sophisticated level, and has made possible, for many isolated cognitive processes, the detailed explanation on how exactly these will change due to ageing. The gains of experience are formulated on a more synthetic level. To describe the nature of experience, the integration of several basic cognitive skills is used. For example, the automation of information processing can require different basic mental processes depending on what kind of information - verbal, auditory, visual or spatial information - is to be processed. In addition, expertise also refers to the acquired knowledge structures and strategies of experts. Research on ageing has not so far addressed the questions whether and how these knowledge structures may change with age. This is why the assessment of the gains for the cognitive skills is more insecure than that of the declines.

A third difficult aspect of the cognitive skill assessment is their dependence on the context, e.g. the workload situation. High workload or monotony are determining factors for cognitive skills like situation awareness, traffic picture updating, multitasking or active problem solving. Another major situational factor is whether an event happens as part of a plan or is unexpected. Both information overload and surprise traffic developments compound the decline due to age. To minimise the influence of such factors on assessments, an average traffic load and a ‘normal’ work situation were assumed for all judgements.

Taking all these limitations into account, an attempt was made to apply the current knowledge about ageing to the cognitive skill list and to come to a conclusion on the vulnerability or persistence of the skills when getting older.

Table 23: Gains and declines for ‘Multitasking’

1	MULTITASKING	Gains	Declines
1.1	Switch attention (e.g. thinking then attending to new strip or pilot's call)		- - processing speed
1.2	Divide attention (e.g. speaking and writing at the same time)		- working memory
1.3	Identify tasks that are highly similar (e.g. instruction that needs issuing to several pilots)	+ useful rules	
1.4	Identify tasks which are more difficult than usual	+ useful rules	

1	MULTITASKING	Gains	Declines
1.5	Time share between tasks	?	?
1.6	Evaluate importance of tasks and prioritise tasks	+ useful rules	
1.7	Find information and navigate between different information sources		- selective attention - - processing speed
	Σ	3 +	6 -

The overall score for 'Multitasking' is minus three points. For this cognitive skill a decrease has to be expected with getting older. This phenomenon has been confirmed by research in cognitive psychology, and by the interviews with ATCOs and the results of this questionnaire.

Table 24: Gains and declines for 'Direct attention to information source'

2	DIRECT ATTENTION TO INFORMATION SOURCE	Gains	Declines
2.1	Identify need for and source of information	+ broad knowledge	
2.2	Scan Radar or any ATC Display Screen Equipment (DSE) or FDPS equipment	+ useful rules	- selective attention
2.3	Attend to FPS		- selective attention
2.4	Attend to information displays		- selective attention
2.5	Attend to reminders		- selective attention
2.6	Ask for information	?	?
2.7	Listen for relevant information	?	?
	Σ	2+	4-

The overall score for 'Direct attention to information source' is minus two points. Although the controllers know better, with increased experience, where to find specific information and what piece of information they have to look for, the cognitive process of selective attention as such shows a decline with age, compounded by the decrease in information processing speed in working memory. Any cognitive task requiring conscious attention draws on the resources of working memory and therefore will suffer from the decline in working memory.

Table 25: Gains and declines for 'Take account of and process external information (from radar, new FPS, coordination, pilot requests)'

3	TAKE ACCOUNT OF AND PROCESS EXTERNAL INFORMATION (FROM RADAR, NEW FPS, COORDINATION, PILOT REQUESTS)	Gains	Declines
3.1	Extract relevant data for traffic assessment visual displays (level, time, route, speed)	++ broad knowledge	
3.2	Extract relevant data for traffic assessment	+ broad knowledge	

3	TAKE ACCOUNT OF AND PROCESS EXTERNAL INFORMATION (FROM RADAR, NEW FPS, COORDINATION, PILOT REQUESTS)	Gains	Declines
	from communication with pilot		
3.3	Check information	+ exactness	
3.4	Integrate information from the various sources		- working memory
3.5	Update mental picture of actual traffic situation	+ knowledge & rules	- spatial reasoning
	Σ	5 +	2 -

The overall score for 'Take account of and process external information (from radar, new FPS, coordination, pilot requests)' is plus three points. Although this process also requires the support of working memory, the positive experience related elements have a stronger influence.

Table 26: Gains and declines for 'Monitoring'

4	MONITORING	Gains	Declines
4.1	Check information sources	+ broad knowledge	- processing speed
4.2	Search for conflicts	+ useful rules	- processing speed
4.3	Respond to conflict information	+ useful rules	- processing speed
4.4	Check for expedition	+ knowledge & rules	
4.5	Update mental picture	+ knowledge & rules	- spatial reasoning
	Σ	5 +	4 -

Both positive and negative influences are effective regarding the process of 'Monitoring'. Although they are almost balanced there may be a slight advantage on the gain side. Monitoring is one of the most basic tasks of the controller job and therefore this mental task is usually highly automated. As automated information processing improves with experience this is another reason why monitoring is considered improving with age.

Table 27: Gains and declines for 'Manage working memory'

5	MANAGE WORKING MEMORY	Gains	Declines
5.1	Prioritise and update currently useful and relevant knowledge in working memory	+ automated processing + knowledge & rules	- - working memory
5.2	Retrieve information from long-term memory	?	?
5.3	Update mental model of position		- processing speed
5.4	Update weather information		- processing speed
5.5	Update position plan		- processing speed
5.6	Check order and priority of actions in plans	+ rules	

5	MANAGE WORKING MEMORY	Gains	Declines
5.7	Use mental or physical cues (e.g. cues, cocking strips, notes or mental tags) to remind oneself of actions required	?	?
	Σ	3 +	5 –

'Manage working memory' achieves an overall score of minus two points. There are some helpful aspects of experience which support the working memory, like automatic information processing or the application of proceduralised knowledge. However, the decline in working memory is the most solid finding in cognitive ageing research and, therefore, it cannot be assumed that the positive gains due to experience are sufficient to counterbalance this decline.

Table 28: Gains and declines for 'Integrate into long-term memory'

6	INTEGRATE INTO LONG-TERM MEMORY	Gains	Declines
6.1	Update aviation knowledge and assimilate into existing knowledge	+ broad knowledge	- learning
6.2	Update ATC knowledge and assimilate into existing knowledge	+ broad knowledge	- learning
6.3	Update knowledge on general ATC procedures and assimilate into existing knowledge (e.g. MATS Pt 1)	+ broad knowledge	- learning
6.4	Update knowledge on position procedures and assimilate into existing knowledge	+ broad knowledge	- learning
6.5	Update knowledge on aircraft performance/ operating procedures and assimilate into existing knowledge	+ broad knowledge	- learning
6.6	Update knowledge of team strengths and weaknesses	+ social skills	
	Σ	6 +	5 -

New information is more easily integrated into long-term memory if there are already existing related knowledge structures. This is definitely the case for experienced controllers who update their knowledge of the job. At the same time the older one gets, the more demanding it is to acquire additional knowledge. This difficulty has been confirmed through the questionnaire data and the results of the interviews conducted with ATCOs, and through literature. Although the overall score for 'Integrate into long-term memory' is plus one point, it is argued that this process should be on the list of neutral skills (neither declining nor improving with age). The increased effort in learning for older people is undoubtedly a strong phenomenon. At the same time learning is an area which, typically, can be influenced by motivation and the insight into the necessity of acquiring certain information to a great deal. However, controllers' attitudes are not taken into consideration in this survey

and therefore a clear decision on this cognitive skill is impossible for the time being.

Table 29: Gains and declines for 'Build up mental picture of traffic situation'

7	BUILD UP MENTAL PICTURE OF TRAFFIC SITUATION	Gains	Declines
7.1	Gather and interpret Information	+ broad knowledge + automated processing	- processing speed
7.2	Check validity of information and review plan	+ exactness	
7.3	Integrate information		- spatial reasoning
7.4	Search for conflicts	+ broad knowledge	
7.5	Respond to conflict information/alert	+ knowledge & rules	- processing speed
7.6	Anticipate future traffic situation	+ knowledge & rules	- spatial reasoning
7.7	Update mental picture	+ knowledge & rules	- spatial reasoning
	Σ	7 +	5 -

The overall score for 'Build up mental picture of traffic situation' is plus two points. Although spatial reasoning and processing speed decline with age, this process relies strongly on existing knowledge structures and automated processing. In total a gain due to experience can be expected.

Table 30: Gains and declines for 'Develop a plan'

8	DEVELOP A PLAN	Gains	Declines
8.1	Evaluate mental picture	+ knowledge & rules	- spatial reasoning
8.2	Handle and process flight plan information		- processing speed
8.3	Anticipate future traffic situation	+ knowledge & rules	- spatial reasoning
8.4	Identify potential conflicts	+ broad knowledge	- processing speed
8.5	Retrieve routine plan from memory	+ broad knowledge	
8.6	Revise position plan	+ knowledge & rules	
8.7	Perform actions before a/c arrives in sector or into area of responsibility	+ knowledge & rules	
8.8	Update mental picture	+ knowledge & rules	- spatial reasoning
	Σ	7 +	5 -

'Develop a plan' achieves plus two points. Again, processing speed and spatial reasoning decline. However, as the planning processing does not normally happen under time pressure, the impact of slower information processing is limited. The usefulness of the broad knowledge structure and the availability of rules and strategies have to be regarded more important and outweighing than the negative processes.

Table 31: Gains and declines for 'Maintain situational awareness'

9	MAINTAIN SITUATIONAL AWARENESS	Gains	Declines
9.1	Update mental picture of actual situation	+ knowledge & rules	- spatial reasoning
9.2	Anticipate future or expected situation	?	?
9.3	Compare actual situation with future situation	+ automated processing	- working memory
9.4	Detect differences between expected and actual situation	+ exactness + broad knowledge	- attention
	Σ	4 +	3 -

'Maintain situational awareness' achieves plus one point. The declines in spatial reasoning, working memory and attention are counterbalanced by the advantages of automated information processing, increased exactness of information processing and the broad memory bank for situations and rules.

Table 32: Gains and declines for 'Active planning'

10	ACTIVE PLANNING	Gains	Declines
10.1	Evaluate mental picture	+ knowledge & rules	- working memory
10.2	Evaluate anticipated traffic situation	+ knowledge & rules	- working memory
10.3	Generate and evaluate the solutions and plans	+ knowledge & rules	- working memory
10.4	Revise existing position control plan, if necessary	+ knowledge & rules	- working memory
10.5	Formulate a new plan	+ knowledge & rules	- working memory
10.6	Check credibility of the plan	+ knowledge & rules + exactness	- working memory
10.7	Evaluate the consequences of the plan	+ knowledge & rules	- working memory
10.8	Plan ahead for consequences	+ knowledge & rules	- working memory
10.9	Be flexible about plans and adapt plan, where necessary	?	?
10.10	Update mental picture	+ knowledge & rules	- spatial reasoning
	Σ	9 +	9 -

For 'Active planning' the scores for gains and declines are balanced. It is a process that both requires resources from working memory and is strongly supported by existing knowledge. Active planning is possibly neutral with regard to ageing processes.

Table 33: Gains and declines for 'Make decision for control actions'

11	MAKE DECISION FOR CONTROL ACTIONS	Gains	Declines
11.1	Check task status	+ exactness	- working memory
11.2	Check for cues on traffic situation	+ exactness	- working memory
11.3	Search for conflicts	+ broad knowledge	
11.4	Formulate decision options	+ broad knowledge	
11.5	Evaluate options against traffic situation / conditions	+ knowledge and rules	- working memory
11.6	Identify routine response	+ knowledge and rules	- processing speed
11.7	Formulate response/plan if necessary	+ knowledge and rules	- working memory - processing speed
11.8	Update mental picture	+ knowledge and rules	- spatial reasoning
	Σ	8 +	7 -

'Make decision for control actions' is, with a plus one score, a cognitive skill which is influenced slightly more positively than negatively. Although the problem of working memory is present again, the skill can rely on the support by knowledge structures, including strategies and rules. In addition, the basic decision-making process is for experienced controllers possibly automated. Not much conscious attention is necessary to take a decision appropriate to a given situation, which contributes to relief of working memory.

Table 34: Gains and declines for 'Solve aircraft conflict'

12	SOLVE AIRCRAFT CONFLICT	Gains	Declines
12.1	Search for conflicts	+ broad knowledge	
12.2	Respond to conflict information/alert		- - processing speed
12.3	Recognise conflict	+ broad knowledge	- processing speed
12.4	Resolve conflict	+ knowledge & rules	
12.5	Update mental picture	+ knowledge & rules	- spatial reasoning
	Σ	4 +	4 -

'Solve aircraft conflict' achieves a balanced number of points. It is not easy to determine the impact of age and experience on this skill, as it is closely depending on the actual situation in which the conflict resolution happens. For example, whether it is an expected or unexpected conflict makes it already quite different. In the case of an unexpected event it has to be assumed that a certain amount of time pressure will occur and therefore the lack of information processing speed would matter. On the other hand, if the conflict is recognised long in advance and can be solved without any hurry, an older controller may find the most elegant solution in his or her rich database of conflict solutions. For the time being this cognitive skill will be regarded neutral.

Table 35: Gains and declines for 'Manage requests and assist pilots'

13	MANAGE REQUESTS AND ASSIST PILOTS	Gains	Declines
13.1	Switch attention		- processing speed
13.2	Update mental picture	+ knowledge & rules	- spatial reasoning
13.3	Check against traffic and the feasibility and relevance of the request	+ exactness + knowledge & rules	- working memory
13.4	Assess impact on own and/or team's workload and prioritise request	+ broad knowledge	- working memory
13.5	Search for conflicts	+ broad knowledge	- working memory
13.6	Formulate appropriate action or response	+ knowledge & rules	- processing speed
13.7	Evaluate the context or nature of request	+ broad knowledge	- working memory
	Σ	7+	7 -

'Manage requests and assist pilots' achieves a balanced overall score. Like for 'solve aircraft conflict' whether the impairing aspects of ageing are a restriction or not highly depends on the situation. Unexpected and unusual requests may require much more effort and involve more working memory resources. However, the more experience one has, the less requests may be considered 'unusual' or 'unexpected', because the controllers have already come across many different requests in the past. For these reasons 'Manage requests and assist pilots' will be treated neutral.

Table 36: Gains and declines for 'Diagnose perceived problem'

14	DIAGNOSE PERCEIVED PROBLEM	Gains	Declines
14.1	Identify possible problem and explanation	+ + problem representation	
14.2	Check external information and gather evidence	+ broad knowledge	- processing speed
14.3	Integrate information		- working memory
14.4	Compare current mental picture with new/observed information	+ broad knowledge	- working memory
14.5	Update mental picture	+ knowledge and rules	- spatial reasoning
	Σ	5 +	4 -

The overall score for 'Diagnose perceived problem' is plus one point. The cognitive skill of 'Diagnosing' requires strong support from working memory. It is definitely a process that does not happen in the mode of automated information processing. At the same time this skill benefits to a large extent from experience with the subject. Problem diagnosis is one of the major advantages which experts achieve in the course of their working life.

Table 37: Gains and declines for 'Active problem solving'

15	ACTIVE PROBLEM SOLVING	Gains	Declines
15.1	Retrieve routine solutions	+ knowledge & rules	
15.2	Review conflict solution		- - working memory
15.3	Generate new solution	+ knowledge & rules	- - working memory
15.4	Anticipate future traffic situation	+ knowledge & rules	- working memory
15.5	Choose solution	+ knowledge & rules	- working memory
15.6	Evaluate solution	+ broad knowledge	- working memory
15.7	Update mental picture	+ knowledge & rules	- spatial reasoning
15.8	Implement solution	+ automated processing	
	Σ	7 +	8 -

'Active problem solving' is, with minus one score, on the list of declines with age. This skill requires more than the recognition of a certain situation and the retrieval of a suitable solution from long-term memory. These processes would be backed up by experience. However, active problem solving involves the dynamic use of the working memory, which is possibly the weakest element of the ageing brain.

Table 38: Gains and declines for 'Diagnose novel situations/problems'

16	DIAGNOSE NOVEL SITUATIONS/PROBLEMS	Gains	Declines
16.1	Identify elements of the novel situation or problem	+ problem representation	- working memory
16.2	Establish relationship between elements (if possible)	+ problem representation	- working memory
16.3	Identify and adapt a situation or problem analogous to novel situation, if possible	+ broad knowledge	- working memory
16.4	Consider any relevant previous experience	+ + knowledge & rules	
16.5	Recall and identify existing knowledge (e.g. rules, information) for an analogous situation	+ + knowledge & rules	- processing speed
16.6	Formulate possible explanations	+ broad knowledge	- - working memory
16.7	Gather evidence to confirm or refute explanations		- working memory - processing speed
16.8	Generate and evaluate new solutions	+ knowledge & rules	- - working memory
16.9	Develop new plan for the novel situation/problem	+ knowledge & rules	- working memory
16.10	Evaluate the consequences of the plan	+ broad knowledge	- working memory
16.11	Update mental picture	+ knowledge & rules	- spatial reasoning
16.12	Use all resources to formulate solution	+ knowledge & rules	- working memory - processing speed
	Σ	13 +	15 -

The cognitive skill of 'Diagnose novel situations/problems' obtains minus two points. Although it is strongly supported by the gains of experience, it cannot be denied that it draws heavily on working memory and attentional resources. Unlike the skill 'Diagnose perceived problem' (cognitive skill n°14), the benefits of experience are not predominant for novel situations. When the problems to solve are unfamiliar, the downsides of an impaired working memory cannot be compensated so easily.

Table 39: Gains and declines for 'Awareness of team situation'

17	AWARENESS OF TEAM SITUATION	Gains	Declines
17.1	Monitor team member's workload	+ knowledge & social skills	- attention
17.2	Monitor own workload and performance	+ self-regulatory skills	- attention
17.3	Monitor own capacity to cope with actual workload	+ self-regulatory skills	- attention
17.4	Manage and regulate workload	+ self-regulatory skills	
17.5	Recognise the need to request assistance before workload exceeds capacity	+ broad knowledge	- attention
17.6	Supervise control room/team (*Only relevant to Aerodrome and Approach Radar)*	+ social skills	
	Σ	6 +	4 -

Team skills – like any other social skills – are difficult to assess from a cognitive point of view. Still, an attempt was made to apply the research finding in this area to team-related cognitive skills. The skill 'Awareness of team situation' achieved plus two points because it is assumed that, with increased experience, the experience in social situations will grow too and that, along this process, social skills will develop and improve. In addition, especially for the management of the own workload, improved self-regulatory skills and self-awareness are regarded helpful. The only identified possible decline relates to attentional processes. Monitoring colleagues' workload and recognising the need for assistance requires the conscious allocation of attention to these issues. Although, with experience, the awareness of the importance of these issues will improve too, some effort still needs to be invested in taking others' workload and needs into account.

Table 40: Gains and declines for 'Team multitasking'

18	TEAM MULTITASKING	Gains	Declines
18.1	Anticipate team members' needs/ capability	+ knowledge & social skills	
18.2	Gather/interpret information proactively for team members	+ knowledge & social skills	
18.3	Share information / Communicate with team members	?	?
18.4	Take into account others' workload	+ knowledge & social skills	

18	TEAM MULTITASKING	Gains	Declines
18.5	Share tasks accordingly	+ knowledge & social skills	
18.6	Take in account the consequences of own actions on other team members and/or other ATSUs	+ knowledge & social skills	
	Σ	5 +	0 -

'Team multitasking' achieved plus five points. This is not only because of the strong improvement of this skill with experience. It is also due to the lack of information and research findings that address team cognitive skills. Even if a decline in elementary cognitive functions may influence the behaviour of an individual in a team, it is assumed that social behaviour – i.e. behaving as a team member – is not impaired by ageing. The opposite is very likely; increased life experience contributes to social skills and supports people in acting as a valuable and supporting team member.

Table 41: Gains and declines for 'Team working'

19	TEAM WORKING	Gains	Declines
19.1	Receive position control plan from previous controller	+ knowledge & rules	
19.2	Assess previous controller's plans before accepting handover	+ knowledge & rules	- working memory
19.3	Concentrate on current and planned future tasks		- working memory
19.4	Adapt previous controller's plan after handover, if necessary	+ knowledge & rules	
19.5	Concentrate on current tasks		- working memory
	Σ	3 +	3 -

'Team working' has a balanced number of points and is regarded as neutral in terms of ageing. Overall team behaviour may improve with age and experience, but the way the sub-elements are formulated for this cognitive skill also point to the declines in working memory. With the currently available information it is impossible to determine which process may outweigh the other.

Table 42: Gains and declines for 'Share mental picture of traffic situation during handover'

20	SHARE MENTAL PICTURE OF TRAFFIC SITUATION DURING HANDOVER	Gains	Declines
20.1	Tidy up strip display and put in place mental reminders for next controller	?	?
20.2	Share information on pressure (high, low, min stack)	?	?
20.3	Share information on runway availability and direction (Westerlies - Easterlies)	?	?

20	SHARE MENTAL PICTURE OF TRAFFIC SITUATION DURING HANDOVER	Gains	Declines
20.4	Share information on airports (ILS, gaps, runway state, work in progress, vehicle movements)	?	?
20.5	Share information on adjacent sectors or ATCCs (bandboxed, split, frequencies)	?	?
20.6	Share information on agreed coordinations	?	?
20.7	Share information on the weather conditions (visibility, winds, avoidance)	?	?
20.8	Share information on non-standard/priority information (NSFs, EATs and holding, NAVAIDs, danger areas, radar/display setup, etc.)	?	?
20.9	Explain strip display and point out significant and cocked strips, tasks/problems that need immediate attention	?	?
20.10	Verify handover and answer any queries	?	?
	Σ	0 +	0 -

The cognitive skill 'Share mental picture of traffic situation during handover' cannot be assessed with the available criteria. These are not applicable to sub-elements of this process. Therefore, this process is regarded as neutral in terms of ageing and experience.

Table 43: Gains and declines for 'Establish mental picture of situation during takeover'

21	ESTABLISH MENTAL PICTURE OF SITUATION DURING TAKEOVER	Gains	Declines
21.1	Signal to handover controller the start of takeover (e.g. plug-in)	?	?
21.2	Evaluate the situation while the outgoing controller performs the handover	+ + broad knowledge	- working memory
21.3	Check for common understanding of handover information	?	?
21.4	Discuss traffic situation with outgoing controller	+ broad knowledge	
21.5	Verify and accept handover only when satisfied	?	?
21.6	Update mental picture	+ knowledge & rules	- spatial reasoning
	Σ	4 +	2 -

The cognitive skill 'Establish mental picture of situation during takeover' achieves an overall score of plus two points. On the decline side are there again working memory functions and spatial reasoning, and on the gains side the broad knowledge bank and the extensive set of rules support the interpretation of the situation found at the takeover time.

4.5 Key Elements

This section summarises the assessment of the cognitive skills. These are split into three areas: cognitive skills that are likely to decline with ageing, cognitive skills that are likely to improve thanks to the gains of experience, and cognitive skills maybe remaining unchanged and therefore neutral in terms of ageing and experience.

Figure 42 below provides an overview of all skills and their categorisation.

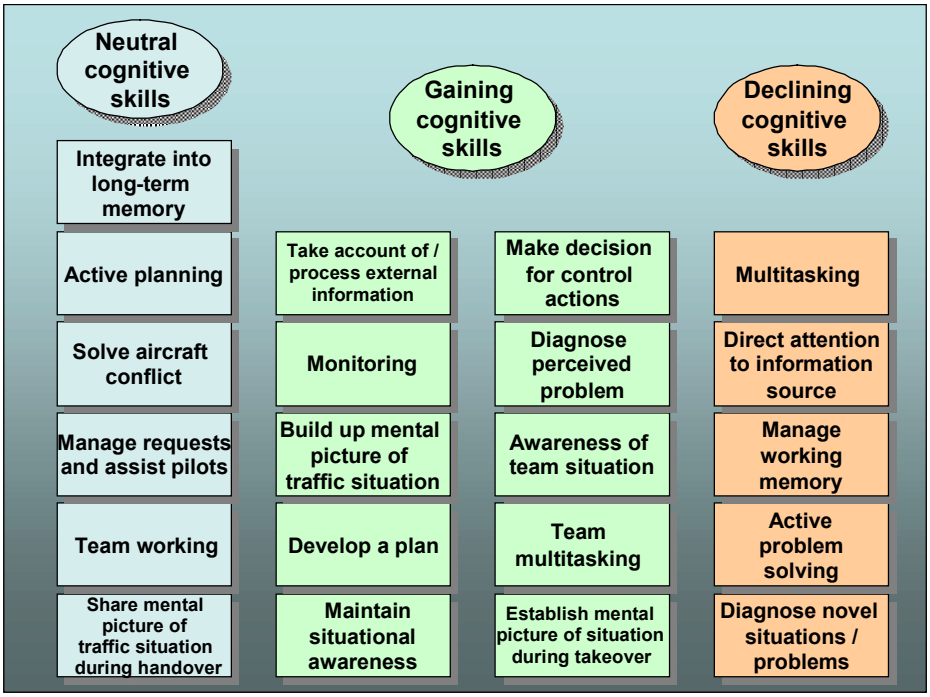

Figure 42: Neutral, gaining and declining cognitive skills with regard to age and experience

Cognitive skills that are likely to decline:

- multitasking,
- direct attention to information source,
- manage working memory,
- active problem solving,
- Diagnose novel situations/problems.

Cognitive skills that are likely to improve:

- take account of and process external information,
- monitoring,
- build up mental picture of traffic situation,
- develop a plan,
- maintain situational awareness,
- make decision for control actions,

- diagnose perceived problem,
- awareness of team situation,
- team multitasking,
- establish mental picture of situation during takeover.

Cognitive skills remaining neutral:

- integrate into long-term memory,
- active planning,
- solve aircraft conflict,
- manage requests and assist pilots,
- team working,
- share mental picture of traffic situation during handover.

Neutral skills are not regarded as key elements of ageing. Only those cognitive skills which will be impacted in a positive or negative way by age and experience are key elements of ageing.

Five key elements are cognitive skills that are likely to decline with age. They are depicted in Figure 43 below.

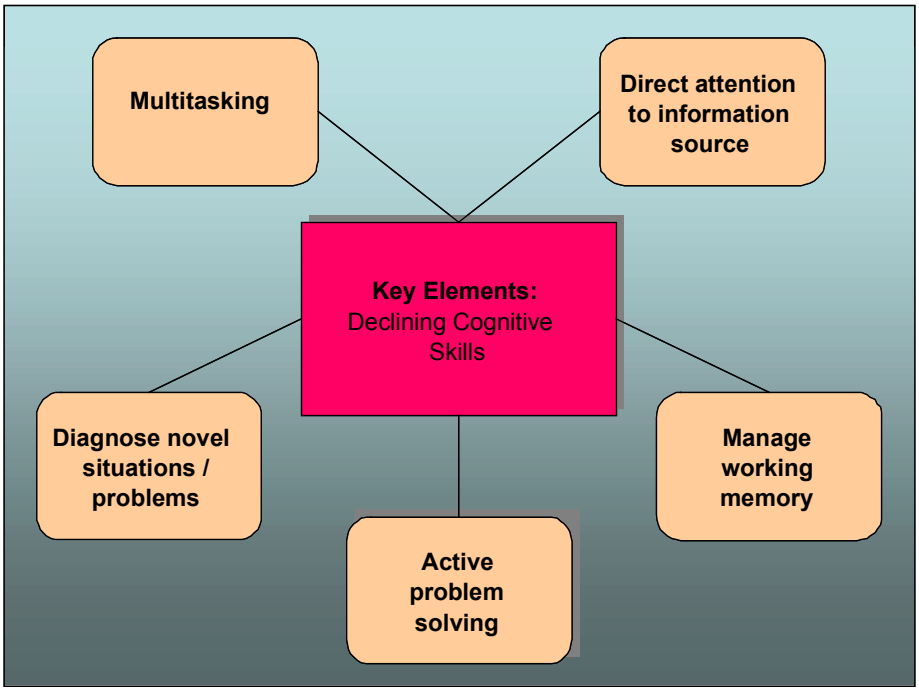

Figure 43: Cognitive skills declining with increased age

Ten cognitive skills show an improvement with age. They are depicted in Figure 44 below.

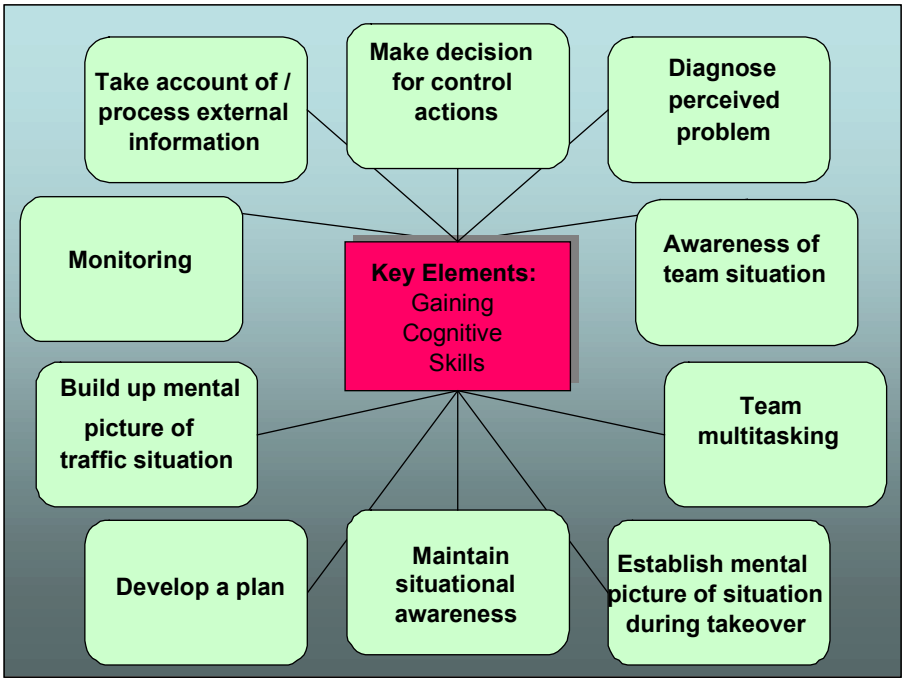

Figure 44: Cognitive skills gaining with increased age

Based on these fifteen key elements (five declining and ten gaining cognitive skills), the next section will develop scenarios on how further work could cover the issue of ageing in ATM.

5. SCENARIO DEVELOPMENT

5.1 Introduction

This section is about the possible approaches for how best dealing with the issue of ageing in ATM. Four levels of actions are available: society, management, the work process and the individual. Obviously, these four levels are not equally easy to influence. This report focuses on the individual and more specifically on the cognitive side of ageing. Concentrating only on the mental side to tackle the problem is however insufficient. This would be too limited an approach to this complex topic. This is why society, management and work processes are also included in this section on countermeasures, even if the focus still lays on the individual cognition.

The analysis of the cognitive skills has revealed what kind of changes will come with age and experience. Fifteen key elements were identified, consisting of those cognitive skills for which a gain or decline with increased age can be expected. The following five cognitive skills are likely to decline: 'Multitasking', 'Direct attention to information source', 'Manage working memory', 'Active problem solving' and 'Diagnose novel situations / problems'. These five skills should be in the focus of attention for the development of countermeasures to cope with ageing. The following ten cognitive skills are likely to improve with experience: 'Take account of and process external information', 'Monitoring', 'Build up mental picture of traffic situation', 'Develop a plan', 'Maintain situational awareness', 'Make decision for control actions', 'Diagnose perceived problem', 'Awareness of team situation', 'Team multitasking' and 'Establish mental picture of situation during takeover'. These ten skills could be used as support to tackle the ageing-related problems. For any countermeasure taken to tackle the downsides of ageing it should be checked whether it decreases the influence of the improving factors. Sections 5.4.2, 'Workplace Design' and 5.5, 'Individual', will refer back to these cognitive skills.

5.2 Society

The highest level of impact one could look at is the society with its means to influence a certain situation or problem. The most important mean available to the society to deal with a given subject is legislation. In the context of ageing in ATM a number of legislative steps are conceivable.

5.2.1 Legislation

Firstly, the adjustment of retirement ages is a strong instrument to deal with ageing and work. This report does not recommend a certain retirement age. This would not only require much more in-depth research, but also – and mainly - a broad public discussion and a consensual decision by all parties

involved, which would take into account all social and financial implications of such a decision.

Secondly, legislation already provides minimal standards in terms of working hours, breaks, workplace design, etc. However, these standards should be carefully revisited and adjusted to the needs of older employees wherever necessary.

5.2.2 Public relations

The importance of public relations cannot be underestimated in its value for the subject ageing. Especially since the pension systems in many countries are more and more under pressure and the unemployment is high, it appears that older employees are regarded a labour pool to be adjusted to the actual needs. When unemployment rate is too high, older employees are forced out of the labour market and into early retirement, and when pension systems are stretched to their limits, people are obliged to increase their working lifetime. Both approaches have in common that they disregard people's dignity and ignore both the capabilities and needs of older employees. What is needed is a public recognition of the value of older employees, which is to the benefit of both the companies and the society. A realistic appreciation of this value could contribute to a more relaxed debate about optimal use of the potential provided by older employees.

A first step in the right direction has been taken through the establishment of several national research programmes on ageing workers, all supported by the European Union (e.g. the FinnAge Programme in Finland or the National Programme about Ageing of the Workforce in Sweden).

5.3 Management

Many aspects could be dealt with here. Management is responsible for everything – at least in the eyes of many employees. This report highlights three elements considered particularly interesting in terms of ageing.

5.3.1 Corporate culture

The corporate culture can make a crucial difference in how ageing is dealt with in a company. Managers aware of the rich value of the experience gathered by older employees will be much more able to optimally use this resource. The individual benefit of experience is also a great benefit for the company in many areas. Managers who can communicate their appreciation of the older colleagues will also motivate this group of people to tackle the challenges implied by their age. An open-minded discussion of the issue is necessary. Treating it as a taboo would instead makes life more difficult for everyone. Only a realistic view on the consequences of ageing and the benefits of experience will allow optimal use of human resources, by assigning the most suitable position in line with personal capabilities.

Associated with the topic is also the safety culture of a service provider. Controllers do not have to be superheroes; they need appropriate professional skills and a sense of responsibility, along with a sense for their personal limits. Denying these limits could have serious consequences on safety. This is why an open approach to the issue of ageing is so important and should be supported by management, for example through internal publications, working groups, etc.

It is the key task of management to avoid the belief that decline in operational performance leads to disadvantages for controllers. Ageing controllers are still highly experienced staff members, who have a lot to offer to their company. Management is responsible for finding optimal solutions, both for the controller and the company.

5.3.2 Health policy

It is a wide-spread prejudice that age goes hand in hand with a decline in health. However, this is not necessarily the case. Physical fitness and health lie within the responsibility of ourselves to a large extent. It has to do with nutrition, physical exercise, sleep/rest behaviour, stress management and the use of medical checks. Although it is the individuals' responsibility to look after their health, managers have to do their utmost to encourage their employees to have a healthy behaviour. It starts with offering healthy food in the canteen, providing sports facilities in the unit and organising regular health checks. Noise-protected and well-equipped rooms are also necessary for those recovering from or preparing for the night shift. In addition, the supply of training courses on stress management is highly recommendable. Working groups composed of management representatives and operational staff, dealing exclusively with health issues in the unit, could be very useful. Such groups could monitor the health status of the staff and come up with suggestions for improvement.

5.3.3 Personnel development

5.3.3.1 Training

Training is an important area to approach ageing declines. Different types of training could contribute to counterbalance the declines of cognitive skills and to strengthen the benefits of experience.

Firstly, regular and frequent refresher training could help to avoid that skills become 'rusty'. In quite a number of cases ageing declines are probably due to lack of practice. Especially training involving traffic scenarios with unexpected events could support older controllers in dealing with the unexpected in their day-to-day work.

Secondly, transition training for the implementation of new equipment should carefully consider the needs of middle-aged and older controllers. A basic requirement is that each controller receives the training time he or she needs

to feel comfortable with the new system. Computer-based Training (CBT) tools, allowing each one to spend as much time as necessary on a certain issue, could be used to support such individual training. Furthermore, the theoretical background knowledge concerning the new system should be made as practical and applicable as possible. Whenever possible a link should be created between the theory and the final application of this knowledge to the new system. For example, hardly used system components could be taught by creating exercises on system recovery in case of system failure.

A rather new idea for ATCO training would be to address the issue of ageing directly in a training course. Ageing is still a sensitive issue. Developing the necessary self-awareness to realise and admit the declines coming with age requires a considerable level of maturity. Since such self-awareness about one's own limits is crucial for a safe working behaviour, lectures on the negative and positive processes of ageing could be organised, which might help breaking the taboo and stimulating the courage to face facts.

5.3.3.2 Career development

Currently, hardly any European national ATC service provider has a systematic approach to ATCO's career development. Considering the results of this survey, a more organised approach to this issue would be highly desirable. Controllers need clear and achievable alternatives to operational work in case they cannot cope with the demand for whatever reason.

The data confirms that there is already a high level of flexibility in the organisation of the tasks. This allows older controllers to find the position appropriate to their competency. This flexibility not only concerns the transition between several ATC services, but also less drastic changes. It can be helpful to have the opportunity to switch from an operational position like executive controller to another operational position like coordinating controller, or from less demanding sectors/positions to more demanding ones. The involvement in tasks other than operational is another way to minimise the strain of the ops room. All kinds of training, supervisory, managerial or administrative tasks, and performance assessment, selection of personnel, incident investigation and technological system development have to be considered here.

The reader may argue that as these options are already available now, no further action should be undertaken to improve the situation. However, more security regarding possible career paths might contribute to tackle the problems associated with ageing more openly, and to find solutions in agreement with all sides involved. This in turn would contribute to the overall safety of the ATC system.

5.4 Work Process

5.4.1 Working hours

Working night shifts has the power to compound ageing impairments. Shift work is a very sensitive issue in terms of ageing. In a profession like air traffic control it is unavoidable to do night shifts. However, the accumulated risks for older employees should not be neglected[15]. From a certain age onwards, which still needs to be determined by medical experts, the number of night shifts should be reduced to the achievable minimum.

Some researchers favour a change in break patterns for older employees. It appears that older colleagues have more but shorter breaks.

A rather simple and efficient way to deal with ageing in the ops room is the shift schedule. Most supervisors take the age of their colleagues into account when allocating them to work positions, although age is of course not the only criteria. Furthermore, switching night shifts with younger colleagues is quite useful - and already a common practice. Another helpful practice is the careful building of working teams: very often allocating an older controller to the planning position and a younger colleague to the executive position turns out to be a good combination.

5.4.2 Workplace design

5.4.2.1 Design of new technological systems

Well-developed technological equipment is one of the most powerful ways to defeat the downsides of ageing. The scope of this survey does not allow to specify design recommendations for certain pieces of equipment. However, some suggestions to be kept in mind for system development are conceivable. Generally, new technological tools should provide a support for working memory, as this is a very vulnerable area. The five declining cognitive skills are closely linked to working memory, that is they require a lot of resources from working memory. Simple little helpers like acoustic or visual reminders would contribute to this requirement as equally as more sophisticated characteristics of new systems, like the automation of complex mental processes.

Furthermore, it is desirable that the equipment supports the planning process and limits the number of unexpected events. As these events are unavoidable in ATC it would be helpful to develop support tools for active problems solving and situation diagnosis.

Another way to support the ageing controller would be to develop equipment in a way that it helps to compensate for the decrease in speed. This would include that all input features are as simple and timesaving as possible (for

[15] An elaboration on this issue can be found EATMP (2003a).

example drop-down menus on the screen should be intelligent and simple). Regarding input tools the use of the mouse has to be questioned. Both speed and precision of input are more difficult to achieve for older controllers when they have to make these using a mouse.

HMI issues should be carefully considered: font size, the use of colour screens and contrasts on the screen are crucial features in the context of ageing. Other HMI issues like usability are also important.

In general it would be an advantage to involve a representative sample of older controllers in the design phase of new equipment. This should be done not only to achieve the commitment of this group for the final product but also, and mainly; for the sake of improving the product. The input of experienced controllers can be of great value. It may also help to capture the positive side of ageing, i.e. the gains due to experience. A smart approach to system design could achieve to build this experience in the new system.

5.4.2.2 Ergonomics of the workplace

The working conditions in a unit should support the controller as much as possible. All rules applying to good workplace design are especially valuable for older controllers. Many aspects could be summarised under the heading of ergonomics. In this section only a few aspects especially relevant for ageing are highlighted.

Lightning of the ops room is an important factor. As eyesight often gets worse with age, a decent supply of light is crucial for older controllers. Ops rooms with daylight are to be preferred. During night times or in ops rooms without daylight an adjustable light source for every workplace is desirable.

The location of information sources should be designed in a way that they are easy to access, without twisting or stretching the body. The ageing body is less tolerant towards this kind of movements. For the same reason chairs and consoles should be individually adaptable.

Hearing sometimes deteriorates with increased age. Therefore, background noise should be minimised, for example by noise lowering floors. In addition, all sources of auditory information should be adjustable in volume.

5.5 Individual

With regard to the individual four attributes are of importance for ageing.

5.5.1 Mental condition

A lot has already been said in this report about cognitive aspects of ageing. It is not repeated here. Cognition is the most important part of the controller job. It is mainly a mental task ATCOs have to carry out every day. Some of these cognitive skills decrease with ageing, some others improve thanks to

the benefits of experience. One thing that is absolutely sure from research is the great difference between individuals in terms of ageing. This is why the individual patterns of decline and improvement in cognitive skills may also vary.

Ageing is an elemental process. Little is known so far on how cognitive ageing can be influenced effectively. Doing regular mental exercise seems to be important to avoid or minimise the loss of skills. However, having a realistic view on one's own skills is equally important. The decline of skills in one area is accompanied by the gain of skills in other areas. It is a sign of maturity and responsibility to be able to admit one's own limits and act accordingly.

5.5.2 Physiological condition

The importance of physical fitness has already been outlined in Section 5.3.2, 'Health policy'. Management can only provide incentives for a healthy behaviour. However, it is up to each one to make use of options like healthy food in the canteen or sports facilities. It remains the responsibility of every employee to actually do something for his or her wellbeing. Adopting a healthy lifestyle will not stop ageing but can contribute to soften its impact or delay the onset of ageing impairments.

5.5.3 Qualification

Controllers are well-trained people. In addition to their professional training they should meet other requirements to remain in the loop. Primarily, they should keep pace with technological development. Sooner or later the computer-based technology will enter the ops room. In most units this process has already happened and some older colleagues are faced with a completely new technology. New computer-based technology offers a challenge to controllers of all ages who are not 'computer-literate'. The best way to prepare for such a step is to familiarize oneself with computers outside working hours, as a spare-time activity, for example by buying and using a PC at home.

Secondly, as not only the technological aspects of the ATCO job are changing, but also the job in general, controllers - just like everybody else today - have to learn to adapt to new job situations. Lifelong learning is not only a slogan, it is a basic requirement of our modern society. A controller who manages to be up-to-date towards her or his job will find it much easier to adapt to changes in the ops room when they occur.

5.5.4 Motivation and attitude towards the job

When interviewed, most ATCOs report that they have a high intrinsic job motivation. Doing the job as such is a pleasure for them and motivates them. This motivation goes along with a high job satisfaction. Being able to keep this motivation intact even after many years doing the same job will

contribute to the overall performance at work. Successful older controllers are very often highly motivated controllers.

The personal attitude towards change may be crucial in mastering the challenges arising from the latest technological developments. A positive attitude can help to remain curious and motivated for taking up the challenges and persisting even when the new equipment turns out to be more tricky than expected. An open-minded approach will support the learning process. However, this does not mean that all shortcomings of a new system should be ignored. It rather means having an open, critical and constructive dialogue with change and development.

One of the findings of this report is that older controllers, on average, feel they have a lower self-confidence than their younger colleagues (see Section 3.3.2.2, Table 10). This is a regrettable result as the analysis in this report revealed that along with a decline in some areas of performance, there are also gains in other fields. This decline in self-confidence may have to do with the generally rather negative attitude towards ageing in our society. Older controllers should be aware of the value of their experience and show through their attitude that they have a lot to offer to their company, even if they no longer work peak traffic hours. In the ATCO job capacity should not be the only thing that matters. After all, safety is the objective number one, and the rich experience of older employees may best contribute to this objective.

6. CONCLUSIONS

This survey aimed to secure results from an initial interview study on ageing in ATM. The outcome of the data evaluation clearly confirms that ageing is an issue in ATM which requires consideration. It is a fact that, due to increased age, there are positive and negative changes in the job performance of controllers.

With the support of this survey, fifteen key elements in relation to ageing and automation in ATM could be identified, five of which are cognitive skills that are likely to decline with ageing, and ten of which are cognitive skills that are likely to gain with experience. The declining skills are 'Multitasking', 'Direct attention to information source', 'Manage working memory', 'Active problem solving' and 'Diagnose novel situations/problems', while the gaining skills are 'Take account of and process external information', 'Monitoring', 'Build up mental picture of traffic situation', 'Develop a plan', 'Maintain situational awareness', 'Make decision for control actions', 'Diagnose perceived problem', 'Awareness of team situation', 'Team multitasking' and 'Establish mental picture of situation during takeover'.

In Section 5, the following four levels of actions identified as useful to tackle the issues related to ageing in ATM were outlined: society, management, work process and individual. Each level provides helpful solutions. These scenarios could be regarded as initial recommendations. As the data gathered within this survey is subjective in its nature, objective experimental data would be required to come to definite conclusions. Since such data is currently not available, a next step in tackling ageing in ATM could be to launch experimental studies focusing on specific questions.

Most of the recommendations in this report will support all controllers, no matter their age. However, older controllers will probably benefit most from them. Older employees are the most valuable resource of a company. It would be extremely short-sighted to force these out of the ops room. If older controllers stopped to pass their experience onto their younger colleagues the overall level of performance in an ops room would necessarily suffer. On the other hand, each controller has to be aware of his or her own limits. The objective is to create a cooperative climate in the ops rooms, in which it be possible to admit one's own limits.

Ageing offers a challenge for ATM. This challenge will not be taken up by ignoring it. The young controllers of today will be the older controllers of tomorrow. In a few years time the service providers will have to face the same ageing-linked problems. Acting and optimising the situation of older controllers now is the best investment in the future.

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ABBREVIATIONS AND ACRONYMS

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

ACC	Area Control Centre
ANOVA	ANalysis Of VAriance
ANSP	Air Navigation Service Providers
APP	Approach Control Centre
ATC	Air Traffic Control
ATCO	Air Traffic Controller / Air Traffic Control Officer *(US/UK)*
ATM	Air Traffic Management
CA	Cluster Analysis
CBPM	Computer-Based Performance Measure
CBT	Computer-Based Training
CC	Crew Chief
CFMU	Central Flow Management Unit
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 *(later renamed 'EATMP' and today known as 'EATM')*

EATM(P)	European Air Traffic Management (Programme) *(formerly known as 'EATCHIP')*
ECAC	European Civil Aviation Conference
ET	Executive Task *(EATCHIP)*
FAA	Federal Aviation Administration
FDPS	Flight Data Processing System
FPS	Flight Progress Strip
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	Human Resources (Domain) *(EATCHIP/EATMP)*
IFATCA	International Federation of Air Traffic Controllers' Associations
MSP	Manpower Sub-Programme *(EATM(P), HRS)*
N	Number of subjects
OJT	On-the-Job Training
OJTI	On-the-Job-Training Instructor
Ops	Operations
PC	Personal Computer
PC	Planning Controller
PRC	Performance Review Commission
RC	Radar Controller
REP	Report *(EATCHIP/EATM(P))*

SA	Situation Awareness
SPSS	Statistical Package for the Social Sciences
Std	Standard Deviation
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)*
SU	Supervisor
TWR	Aerodrome Control (Tower)
UK	United Kingdom
US	United States

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CONTRIBUTORS

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The author hopes this work will feed back to the operational 'front line' and will contribute to an advanced understanding of the issue of ageing and - in the longer range - to improve working conditions in operational units.

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APPENDIX: THE QUESTIONNAIRE (PAPER VERSION)

Age, Experience, and Automation in European ATM

Questionnaire

What is this project about?

European ATM is facing a period of substantial change. Automation of technical equipment has reached an unprecedented level. However, it remains the air traffic controller who has to deal with this equipment. We take a close look at the role of the human in the ATM system in a project called SHAPE (Solutions for Human-Automation Partnership in European ATM).
Currently, Human Factors don't know much about the role of age and experience in an air traffic controller's job. However, we believe automation must suit all controllers! We would like to find out about the relationship between age and experience of the controller and automation. Our aim is to improve system design and training for new
systems to fit all controllers.
It is only when we have a large amount of data available to us, that we can draw representative conclusions on certain issues. A questionnaire is an efficient way to collect data. By answering our questions you help us to complete the big picture. Each individual contribution to the pool of data is valuable and important.

How to fill out this questionnaire:
The questions are asked in different forms: For some questions you are required to fill in some text. For other questions you have to tick boxes and for some others you have to use a rating scale when ticking the boxes.
When answering the questions please think about your own experience with the issue. If you believe that some of the questions do not apply to your experience because you are too young just answer them on the 'disagree'-side of the rating scale.
The average time to fill out the questionnaire is 40 minutes.
Your data will be treated confidentially.
We would appreciate if you would be able to fill out the questionnaire as soon as possible. The latest return date is the 28th February 2002. Please return it to the address below.
This questionnaire is also available in an electronic format on internet: http://www.eurocontrol.int/eatmp/humfactors/index.html
Thank you for your participation.

Michiel Woldring
Sub-Programme Manager
Human Factors and Manpower Unit
EUROCONTROL HQ

Judith Rothaug
Human Factors Expert
Human Factors and Manpower Unit
EUROCONTROL HQ

For further information on this project contact aea.survey@eurocontrol.int

Please send this questionnaire to:

EUROCONTROL
DIS/HUM
Rue de la Fusée 96
1130 Brussels
Belgium

Please tick the appropriate boxes and fill in the blank spaces.
When answering the questions please think about your own experience with the issue.

1. Your background as a controller

1.1 At which ATC Centre do you work? _____

1.2 Are you ☐male or ☐female?

1.3 What is your age? _____ years

1.4 When did you begin to work as an air traffic controller? _____

1.5 In the course of your working life, which areas have you worked in?

☐ Area control. **If yes, for how many years? _____**
☐ Approach/TMA. **If yes, for how many years? _____**
☐ Tower. **If yes, for how many years? _____**
☐ Oceanic. **If yes, for how many years? _____**

1.6 Where do you currently work?

☐ Area control
☐ Approach/TMA
☐ Tower
☐ Oceanic

1.7 For how long have you been working in your current position?

_____years, _____months.

1.8 In the centre/unit you are currently working at, which positions are you qualified to work in with your licenses/validations?

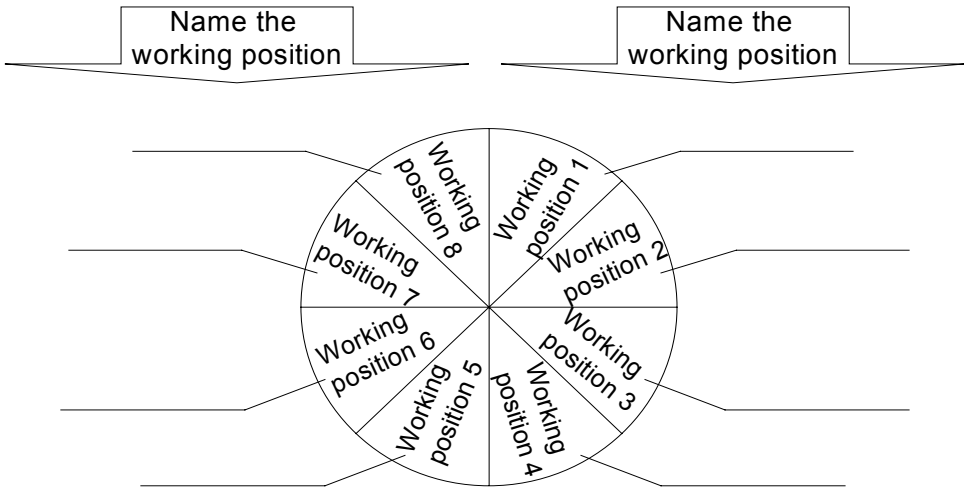
☐ Planning controller
☐ Executive/radar controller
☐ Chief controller/team chief
☐ Supervisor
☐ Others; please specify _____

Please tick the appropriate boxes and fill in the blank spaces.
When answering the questions please think about your own experience with the issue.

1.9 How many validations (average) do controllers have at your unit?

_____ validations.

1.10 Please name all the working positions for which you have a validation.



If you work more than 8 working positions please name the remaining here:

_____

The following three questions should be answered in the table below.

1.11 Which three working positions do you mostly work?

1.12 Which working positions do you work the most, medium or least?

1.13 What is the peak traffic load of these working positions?

Working position	**Working most, medium or least**	**Peak traffic load (aircraft per hour)**
Example: *Upper West*	***Example:*** *Most*	***Example:*** *35*

Please tick the appropriate boxes and fill in the blank spaces.
When answering the questions please think about your own experience with the issue.

1.14 How long is your average working week (in hours)? _____ hours.

1.15 Do you work ☐ **100% (fulltime)?**
☐ **99 – 80% (part-time)?**
☐ **79 – 50% (part-time)?**
☐ **less than 50% (part-time)?**

1.16 During your working week, do you have other responsibilities in addition to your operational duty?

☐ Instructor on-the-job training
☐ Instructor institutional, simulator or other training
☐ Involved in training projects (e.g. exercise design, transition training)
☐ Supervisor/Watch Manager
☐ Other managerial/administrative tasks
☐ Performance assessment/evaluation
☐ Selection of personnel
☐ Incident investigation
☐ Are you involved in technical projects? If yes, please specify the projects:

_____

_____

☐ Are you involved in other projects? If yes, please specify the projects:

_____

_____

1.17 How many hours per week do you spend on the above tasks? _____ hours.

1.18 What is the mandatory retirement age for operational controllers in your country?

_____years.

1.19 What is your preferred retirement age? _____ years.

☺

You have already completed more than half of the questions!
The rest of the questionnaire is mainly concerned with ratings which are very quick.

Please tick the appropriate boxes and fill in the blank spaces.
When answering the questions please think about your own experience with the issue.

2. Technological system change

2.1 Have you had an upgrade of equipment at your workplace within the past 5 years?

☐ Yes ☐ No

2.2 If yes, what where the main changes in this upgrade? More than one answer is possible. If no, continue with Section 4, 'Influence of Age and Experience on Job Performance'.

☐ Software upgrades of radar display (e.g. windows interface)

☐ Automated aids for traffic planning (e.g. trajectory prediction tools)

☐ Automated aids for conflict detection (e.g. Short-term Conflict Alert)

☐ Additional information displays (e.g. for weather data)

☐ Approach/departure support tools

☐ Automated support for airport surveillance

☐ Air-ground datalink; strip-less system

☐ Software upgrade in Flight Data Processing system

☐ Hardware upgrades in Flight Data Processing system

☐ New input devices (e.g. mouse, keyboard, touch screen, etc.)

☐ Others. Please specify: _____

_____

2.3 What were the most helpful aspects of this upgrade for you?

- _____
- _____
- _____
- _____

2.4 What were the most difficult aspects of this upgrade for you?

- _____
- _____
- _____
- _____

Please tick the appropriate boxes and fill in the blank spaces.
When answering the questions please think about your own experience with the issue.

3. Transition training

3.1 Please indicate your view on the following statements.

	Very much disagree	Dis-agree	Some-what disagree	Some-what agree	Agree	Very much agree
Prior experience with computers (e.g. PC at home) helps me in the transition to a new system.	☐	☐	☐	☐	☐	☐
It confuses me when our training simulator has bugs (technical problems) in the new system it is simulating.	☐	☐	☐	☐	☐	☐
Being personally involved in the system development makes it easier for me to make the transition.	☐	☐	☐	☐	☐	☐
Computer-based Training (CBT) tools are helpful to me to familiarize myself with the new system.	☐	☐	☐	☐	☐	☐
The amount of information I have to learn places a high demand on me.	☐	☐	☐	☐	☐	☐
I would prefer to have more training time for the transition training.	☐	☐	☐	☐	☐	☐
I would prefer a flexible adaptation of the training time to individual requirements.	☐	☐	☐	☐	☐	☐

4. Influence of experience and age on job performance

Please indicate your view on the following statements.

	Very much disagree	Dis-agree	Some-what disagree	Some-what agree	Agree	Very much agree
4.1 Experience helps to compensate for ageing effects.	☐	☐	☐	☐	☐	☐

4.2 What kind of influence can ageing have on an air traffic controller's job performance after the age of 40?

Positive ☐ No influence ☐ Negative ☐

4.3 If your last answer was 'negative', at what age do you think performance starts to decline?

_____years.

Please tick the appropriate boxes and fill in the blank spaces.
When answering the questions please think about your own experience with the issue.

4.4 Do you believe older controllers are better at certain tasks? Please indicate your view on the following statements.

	Very much disagree	Dis-agree	Some-what disagree	Some-what agree	Agree	Very much agree
Older controllers are better as supervisors or in other leadership positions than younger controllers.	☐	☐	☐	☐	☐	☐
Older controllers are better at handling unusual situations or emergencies than younger controllers.	☐	☐	☐	☐	☐	☐
Older controllers are better as instructors and trainers than younger controllers.	☐	☐	☐	☐	☐	☐
Older controllers are better at planning the traffic than younger controllers.	☐	☐	☐	☐	☐	☐
It is rather a question of individual differences; more than age it is a question of where the controllers' strengths are.	☐	☐	☐	☐	☐	☐
Older controllers are not better at certain tasks.	☐	☐	☐	☐	☐	☐

4.5 Can you think of any other tasks where older controllers might be better than their younger colleagues?

_____

4.6 Please consider the following list of possible effects experience and age can have on job performance. Please indicate your view on the following statements.
Please think about your own experience from the perspective of your current age!

With further job experience and an older age…	Very much disagree	Dis-agree	Some-what disagree	Some-what agree	Agree	Very much agree
…I have better knowledge of situations and solutions.	☐	☐	☐	☐	☐	☐
… my working speed decreases.	☐	☐	☐	☐	☐	☐
…I work more safely.	☐	☐	☐	☐	☐	☐
…health problems increase (e.g. eyesight gets worse, high blood pressure, back problems, etc.).	☐	☐	☐	☐	☐	☐
…my self-confidence is higher.	☐	☐	☐	☐	☐	☐
…I can handle less traffic.	☐	☐	☐	☐	☐	☐
…I know the 'tricks' of the job.	☐	☐	☐	☐	☐	☐

Please tick the appropriate boxes and fill in the blank spaces.
When answering the questions please think about your own experience with the issue.

4.6 Continued: Please consider the following list of possible effects experience and age can have on job performance. Please indicate your view on the following statements. Please think about your own experience from the perspective of your current age!

With further job experience and an older age…	Very much disagree	Dis-agree	Some-what disagree	Some-what agree	Agree	Very much agree
…my flexibility decreases.	☐	☐	☐	☐	☐	☐
…my efficiency usually increases.	☐	☐	☐	☐	☐	☐
…the job in general gets more demanding for me.	☐	☐	☐	☐	☐	☐
…I am better at managing my workload.	☐	☐	☐	☐	☐	☐
…learning gets more difficult for me.	☐	☐	☐	☐	☐	☐
…my self-confidence is lower.	☐	☐	☐	☐	☐	☐
…my work becomes routine for me.	☐	☐	☐	☐	☐	☐
…multitasking (i.e. doing more than one thing at a time, e.g. strip writing and making a phone call) gets more difficult for me.	☐	☐	☐	☐	☐	☐
…my ability to anticipate the traffic development improves.	☐	☐	☐	☐	☐	☐
…my mental traffic picture is more limited.	☐	☐	☐	☐	☐	☐
…I become better at handling unusual situations and emergencies.	☐	☐	☐	☐	☐	☐
…I experience problems with decision-making.	☐	☐	☐	☐	☐	☐
…I become better at planning.	☐	☐	☐	☐	☐	☐
…it becomes harder for me to cope with stress.	☐	☐	☐	☐	☐	☐
…I am better at prioritising the tasks.	☐	☐	☐	☐	☐	☐
…my memory gets worse.	☐	☐	☐	☐	☐	☐
…I have a broader context knowledge (e.g. about aircraft performance, weather, etc.).	☐	☐	☐	☐	☐	☐
…it gets more difficult to keep attention over a sustained period of time.	☐	☐	☐	☐	☐	☐
…my recovery after working hours takes longer.	☐	☐	☐	☐	☐	☐

Please tick the appropriate boxes and fill in the blank spaces.
When answering the questions please think about your own experience with the issue.

4.7 Can you think of any other effects of experience or age?

_____

5. Job demand

Please indicate the degree of demand you experience under the following conditions:

		Very low	Low	Rather low	Rather high	High	Very high
5.1	**How demanding is your job in general for you?**	☐	☐	☐	☐	☐	☐
5.2	**How demanding are peak traffic periods during a working day for you?**	☐	☐	☐	☐	☐	☐
5.3	**How demanding is the summer season with high traffic for you?**	☐	☐	☐	☐	☐	☐
5.4	**How demanding is working night shifts for you?**	☐	☐	☐	☐	☐	☐

6. Factors influencing job performance

6.1 Please indicate your view on the following statements.

	Very much disagree	Dis-agree	Rather dis-agree	Rather agree	Agree	Agree very much
Working part-time (partly on position – partly other tasks like training) has an influence on my performance.	☐	☐	☐	☐	☐	☐
The negative effects of age are stronger on the radar (executive) position.	☐	☐	☐	☐	☐	☐
The negative effects of age are stronger in high traffic load situations.	☐	☐	☐	☐	☐	☐
High motivation supports me in doing a good job.	☐	☐	☐	☐	☐	☐

6.2 Can you think of any other aspects which might influence the job performance of air traffic controllers?

_____

Thank you!

What we will do with your data.
Your answers will be treated confidentially. You don't even have to tell us your name. The results of this questionnaire survey will be published as a report by the EUROCONTROL Human Factors and Manpower Unit.

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