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Integrated Task and Job Analysis of Air Traffic Controllers Phase 1

Development of Methods

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Abstract

The development and the elements of a standardised Integrated Task Analysis (ITA) procedures are described. The main purpose of this task analysis is to describe the job and tasks of Air Traffic Controllers (ATCOs) from a perspective which focuses on the cognitive processes. Its main aim is to throw some light on the processes which take place in the controller's mind while he is working. For this purpose a cognitive interview has been developed, which addresses the controller's information processing for different tasks. The interview is supplemented by a set of observational methods. A flight-progress reconstruction interview links the results of the interview to those of the more classical task observation. To complete the methods, an interview addressing organisational aspects and some methods for assessing the controller's workload and stress are provided.

Keywords

Integrated Task Analysis (ITA) | Cognitive Task Analysis (CTA)
Cognitive Interview | Flight-progress reconstruction

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EXECUTIVE SUMMARY

This document is a report on Phase 1 of the development and application of a generic Integrated Task Analysis (ITA) for Air Traffic Controllers (ATCOs) which has been contracted out to the 'Institute for Evaluation Research' (Institut für Begleitforschung, IfB) by the Human Resources Domain (HUM) of the European Air Traffic Harmonisation and Integration Programme (EATCHIP).

It is intended to provide the reader with an overview of the basic elements of ITA, and produce initial results on its application. The generic method can be supplemented by diverse methods according to specific additional questions which will be discussed in the text.

The philosophy of ITA assumes that neither a pure Cognitive Task Analysis (CTA) nor a pure behaviourally-oriented task analysis will be sufficient to provide a thorough understanding of controllers' jobs and tasks. The current task-analysis method aims to combine both the cognitive and behavioural aspects of the ATCO's job.

The results of Phase 2 'Application and Results for En-Route Controllers' and Phase 3 'Baseline Reference of Air Traffic Controllers Tasks and Cognitive Processes in the European Civil Aviation Conference (ECAC) Area' will be presented in subsequent reports.

Chapter 1, 'Introduction', outlines the purpose and scope of the project.

Chapter 2, 'Theory of Task Analysis', summarises the theoretical assumptions of task analyses in ATC and outlines the rationale of moving from isolated to integrated approaches and methods.

Chapter 3, 'Task-Analysis Methods', gives an overview of current elements of cognitive and action-oriented task analysis and supplementary methods.

Chapter 4, 'Development of Integrated Task Analysis', outlines the theoretical assumptions and rationale for the development of the ITA method.

Chapter 5, 'Elements of Integrated Task Analysis', describes the generic elements of the ITA (cognitive interview, action-oriented task observation, flight-progress reconstruction and supplementary methods).

Chapter 6, 'Empirical Data Collection and Analysis', gives an overview of the data collection, documentation and analysis in various non-representative Area Control Centres (ACCs) of the ECAC area.

Chapter 7, 'Initial Results', gives a summary of initial findings during the conduct of the ITA in various ACCs of the ECAC area.

Chapter 8 gives recommendations for the application of the ITA.

The annexes contain an overview of action-oriented task-analysis systems, the ITA Project outline, references, a brief list of definitions, and abbreviations. The task-analysis material (questionnaires, interview guides, worksheets, etc.), guidance and recommendations for their use, and application may be found in a technical supplement to this document.

This technical supplement will be kept as a living document throughout the three project phases and is available on request (Contact Mrs Dominique VAN DAMME, fax: +32-2-729.9149).

The release of this report is based on the current knowledge gained in the course of Phase 1. A revision, however, might be necessary after completion of the whole project.

1. INTRODUCTION

1.1 Purpose

With increasing air traffic in Europe, new demands are being made on ATCOs. To achieve an adequate selection process, an effective training programme, a proper licensing system and adequate knowledge of new Air Traffic Management (ATM) systems as well as an optimal job sharing between human and machine system parts, it is urgently necessary to understand the complex cognitive performance of controllers. More knowledge is required on how controllers build and maintain their mental picture of the traffic situation, how their decision processes work in routine and in conflict situations, and how they organize the pre-planning and planning of the traffic flow, as well as their actual technical management of the air traffic depending on fast-changing situational conditions.

In addition, a cognitively-oriented task analysis should highlight the most important cognitive processes of the multiple tasks of an ATCO, i.e. perception of information, information selection processes, information integration and planning, as well as decision-making and evaluation of the whole traffic situation and the ATC system. Previous task analyses of ATCOs using classical methods do not focus explicitly on the cognitive aspects of ATC and the problems of cognitive multi-tasking. In most instances up to now, the cognitive processes of an ATCO have to be inferred from behaviour analysis and analysis of the work tasks.

By stressing the basic planning processes, the activities of an ATCO are presented differently from those which can be found using more classical task analysis. These classical approaches are oriented towards objective demands and towards behaviour, whereas the cognitive analysis is oriented towards the goals and plans of an ATCO, the mental representation of the traffic situation and the guidance of the activity by plans, rules and skills. The integration of different approaches in an ITA will enable cognitive processes to be related to the controller’s action and the complex interplay of cognitive processes, action and workload to be understood.

The resulting ITA method will be a generic framework, which enables the ATCO’s tasks and jobs to be viewed from a cognitively-oriented position. It should be taken as the basis for an ECAC-wide method, characterizing the different activities of ATCOs.

A brief example may serve to illustrate the impact of ITA. Consider the situation of a free flight. In this case, the complexity of the traffic situation increases exponentially with the number of aircraft (a/c) being controlled. Thus, the air traffic regulations applied to organizing the traffic according to fixed destinations and with well-defined flight levels allow the complexity of the controller’s tasks to be reduced. It should be kept in mind, however, that one or two a/c crossing the main routes can drastically increase the complexity and thus exponentially increase the workload. This non-linear process shows how important the understanding of the processes used in maintaining the traffic picture is.

1.2 Scope

The project will commence with the development and application of a task analysis, which integrates methods from CTA with methods from action-oriented task analysis and from stress analysis. The development of the methods will focus on the following procedures:

- cognitive interviews,
- action-oriented task observations,
- flight-progress reconstruction,
- supplementary methods,
- integration of currently existing task-analysis results.

The methods will be presented in English. A German translation exists from the start. Data have been collected in seven non-representative European ATC units. This step will be extended to obtain a representative description of different jobs and tasks of controllers. Thus, in Phase 2 of the project, the methods will be used to describe the jobs and tasks of 48 en-route controllers in different European ATC units. In Phase 3, different ATC units (aerodrome, departure-approach, en-route) will be compared using data from 72 controllers. Different levels of traffic density, differences in the specifications and controllers' experience level will guide the data analyses.

A guideline for data analyses has been developed which will be briefly presented in the current paper.

The analysis will explain the basic processes of ATC, and a first and second level breakdown of the most important tasks including their cognitive and behavioural aspects will be conducted in Phases 2 and 3.

Implications of the initial results obtained within the developmental phase of the ITA will be presented in the current report from 8 instructors and 24 controllers, and some recommendations and conclusions will be made.

1.3 Characterization of the Approach

The ITA is based on the 'Model of the Cognitive Aspects of Air Traffic Control' (EATCHIP, 1997). One of the basic assumptions derived from this model is that ATC is basically governed by top-down processes. This does not exclude the situationally-determined reflective skill-based behaviour of the controller but it stresses that this behaviour is embedded in a kind of planned action.

One of the major purposes of this study is to establish a cognitively-oriented task-analysis method to enable the cognitive top-down processes to be accounted for. At the same time, the interviews and the empirical data will be used to validate this basic assumption and to outline the limits of these top-down processes. One limitation which has already emerged from the basic validation interviews of the model of the cognitive aspects of ATC is the breakdown of a controller's traffic picture. In this case, the controller's activity mainly consists of reactions to situational events, and the overview of the situation is lost.

A second feature which characterizes the current approach is the methodological pre-requisite of a multi-level approach. This multi-level approach, which has been well-established in stress psychology and other areas of empirical psychology, ensures that empirical data from one observational level are cross-validated by other kinds of data. In qualitative- oriented scientific approaches, this methodological principle has been termed 'triangulation'. In addition to the more logical considerations given above, this methodological principle of triangulation makes it necessary to include more than behavioural observation or the controllers' 'self-report' in the data collection. Thus, the so-called integrated approach of the current task analysis is based on psychological as well as methodological considerations.

From a psychology point of view, the integrated approach is necessary because cognitive processes are important; at the same time, the highly automated action is rarely represented verbally with the result that experts are often unable to give a precise description of their activity, or of the plans and cognition's which guided their action. The basic methods which constitute the ITA are:

– the cognitive interview technique,
– the flight-progress reconstruction technique,
– observations at the work position.

These data were supplemented by:

– an organisational interview;
– questionnaire data;
– registration of heart rate and heart rate-related observations at the workplace.

More arguments in favour of an ITA based on cognitive interviews and supplemented by methods can be found in Seamster, Redding and Kaempf (1997).

Finally, the approach can be characterized as a generic one. The idea was to provide a task-analysis method which could be applied throughout the ECAC area on different working positions in different ATC units. In some cases, this generic method needs to be customised to the local conditions and it can be supplemented by additional methods. Alternatively, the basic elements can be used throughout and the basic recommendations should be taken into account, even if the method is used to answer more specific questions. The method can be used by observers who have undergone an introductory training. It takes about three hours of interview, and 90 to 120 minutes of task observation. In addition, it is useful to have an outline of the organizational structure and the basics of work organization in the ATC unit concerned. An interview guideline for obtaining this information is included in a technical supplement of the ITA.

The technical supplement includes interview guides, observational grids, questionnaires and a brief ‘how to use’ guide for each of the methods. It will be verified and amended in the course of the project, and finalised in summer 1999. The current working draft can be obtained from the EUROCONTROL DED 5 Human Resources Bureau (fax: +32-2-729.9149).

2. THEORY OF TASK ANALYSIS

2.1 Task Analysis in Air Traffic Control

In his comprehensive book on ‘Human Factors in Air Traffic Control’, David Hopkin (1995) delineates 16 different reasons for compiling an ATC task analysis. The most important reasons should be mentioned briefly:

- To reveal the ways in which ATC jobs differ from each other and the ways in which they are all similar, as a rationale for categorizing ATC jobs;
- To provide a basis for selecting ATCOs and for evaluating selection procedures in relation to job requirements;
- To provide a framework and policy for the training of controllers;
- To develop a tool for the quantitative evaluation of different ATC jobs, in terms of their pay, status, gradings or responsibilities;
- To classify or categorize measures that can be applied to appraise the performance of individual controllers;
- To provide a means to indicate and quantify the main effects of proposed job changes resulting from computer assistance, new forms of information, increased traffic-handling capacity or a new ATC system;
- To show which jobs are more compatible with each other, or would be most easily split or combined;
- To provide a tool for manpower planning;
- To show how the hierarchy of job characteristics and responsibilities relates to organizational and managerial structures;
- To devise jobs to be studied by simulation, evaluation, research or modelling methods, and to revise job descriptions accordingly;
- To show how a job enables those who do it to meet their legal obligations.

Classical forms of task analysis are scarcely able to meet these criteria, especially as far as future developments are concerned. Task analyses should aid the process of selection, training and licensing of ATCOs for their jobs in the ATM systems of the future. In addition, task analyses should help to set up a proper configuration of the Human-Machine Interfaces (HMIs) and the allocation of different tasks to different sub-systems of future ATM systems. This includes the allocation of tasks between human and machine as well as a proper division of the ATCOs’ jobs into tasks. To handle an increasing amount of traffic, the traditional idea of making up smaller sectors and thus increasing their number is a strategy with limited success.

The amount of co-ordination necessary increases non-linearly with the number of sectors to be handled. In order to account for the increasing amount of traffic, it will be necessary to review the classic functions of controller (aerodrome, departure-approach, en-route) and possibly refine the division of tasks. An example of how a better co-ordination between the approach of different adjacent airports can be handled is shown by the Terminal Manoeuvring Area (TMA) controller established in the United Kingdom.

Questions arising from these different areas can only be answered if the controller's cognitive processes are thoroughly taken into account. With traditional forms of task analysis, cognitive processes have to be inferred and no data are available on how objective, reliable and valid these inferences are. It was from this weakness in traditional task analysis that the CTA, which applies methods from cognitive sciences and cognitive psychology, emerged. These methods can be used to elucidate the different cognitive processes involved in ATC, and to reveal the strong and weak points of human information processing in ATC. While on the behavioural level and the level of task description, ATC is obviously a kind of complex multi-tasking, CTA will be able to show which kinds of cognitive processes can be conducted in parallel and which kinds of processes are sequentialized by the controller.

2.2 Model on Cognitive Aspects of Air Traffic Control

The current ITA is based on a 'Model of the Cognitive Aspects of Air Traffic Control' (EATCHIP, 1997). It was developed before the present work on the task-analysis method was started. The model structures the most important mental processes and stresses the role of active planning processes in ATC. It emphasizes the continuous comparison of the anticipated traffic situation with the actual traffic situation. Therefore, continuous anticipation within the mental picture of the situation and proactive planning, based on a mental model, dominates the activities and is referred as a top-down process.

The model of cognitive aspects of ATC delineates some basic structural components and cognitive processes which will be important in describing the ATCO's job and tasks from a cognitive point of view. In cognitive psychology, it is known that some of the memory structures of the human information processing system are of limited capacity, while others seem to be of nearly unlimited capacity. Thus, the so-called working memory in many information processing models is a kind of bottleneck because of its limited capacity and vulnerability to interference. As everybody knows, the short-term working memory can easily be disturbed by interfering information from other areas or even from one's own emotional reactions.

Conducting complex tasks is only possible as long as the different goals are kept in mind. This function of the Process Control System (PCS) - also termed 'protocol memory' - is a second element of human information processing, which is error-prone. Therefore, the PCS of the model on cognitive aspects of ATC is a second structural element of high importance for task and job analysis and for error analysis.

According to the model on cognitive aspects, one of the most important tasks of an ATCO is to establish and keep situational awareness. This means that the mental model (e.g. knowledge, experience) of the sector has to be adjusted to the actual traffic conditions and their environmental background and the actual restrictions of traffic flow, which results in a situationally adequate mental (traffic) picture. Based on this mental picture, it is possible to plan and anticipate future traffic events (see Figure 1). The anticipated traffic events have to be continuously compared with the situational input. As long as only unimportant small misfits between picture and situation appear, situational awareness will be kept. Situational awareness breaks down when there are unexplained and unexplainable discrepancies between the anticipated and the real traffic situation.

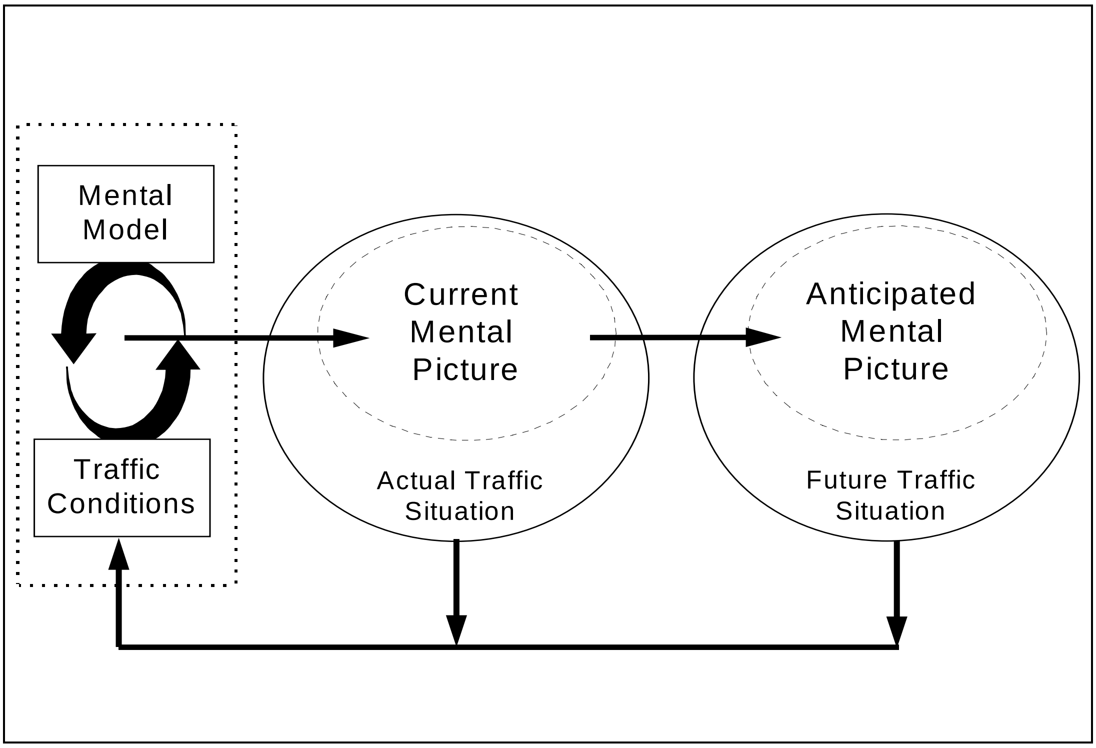

Figure 1: Individual Situational Awareness Loop

By highlighting the top-down aspects of ATC and the anticipation-action-comparison loop, the cognitive model of ATC points to one of the strongest features of human information processing. As a general principle, biological systems are much better at anticipating future situations than technical systems. One major reason is the difficulty of accounting for non-linear developments. As an example, Short-Term Conflict Alert (STCA) systems can be used. These systems often raise false alarms because the interpolated trajectories are linear and cannot take into account the fact that a turn has already been cleared.

Another feature which is pointed out by the cognitive model of ATC is the high flexibility of human information processing. This again is a weak point in current technical systems.

2.3 Assessment of Cognitive Processes

As the cognitive processes cannot be observed directly, one has to rely on the controller's self-assessment or on indirect methods in order to deduce the cognitive processes. To link these results to task analysis and task descriptions on the behavioural level, it is necessary to cross-validate them with behavioural observation.

Behavioural observation is also necessary because experienced controllers act in a highly automated way, even when carrying out complex actions. Because of this automation, very important steps of an action will often be omitted in verbal descriptions. A check is therefore necessary to test the completeness of verbal descriptions of an action.

Another problem which has received a much methodological attention is the bias of controller self-assessments. In many instances, the verbal description of an action has to be considered as a subjective reconstruction of the activity, which could deviate substantially from reality. The discussion on the problems of self-reports on one's own cognitive processes ('introspection') have been discussed since the beginning of cognitive psychology at the start of the century, and still most of these problems are unresolved. Again, this shows the necessity of validating a controller's report data by behavioural observation and other methods.

Ryder and Redding (1993) termed a traditional task analysis in combination with CTA 'Integrated Task-Analysis Methodology'. This approach has been adopted for the current situation. The cognitive aspects were integrated into the task-analysis results by means of an ITA. Ryder and Redding (1993) view ITA methodology as a three-step approach to task analysis. First of all, a kind of overview is generated; second, a level of expertise is defined, and third, a CTA is conducted using an expert-novice paradigm. The results are validated by observational methods.

The major disadvantage of CTAs conducted up to now is their lack of standardization. What methods are selected to obtain what results by what observers in what situation is decided according to the different subjective preferences and skills of the researchers conducting the analysis. A second problem is that some of the methods employed in CTA are extremely time-consuming and normally can only be used by well trained research groups. On the other hand, Seamster, Redding and Kaempf (1997) were able to give an overview of the different methods used in CTA up to now. From the methods available, the core approaches to analyse cognitive processes of ATC were selected for the current standardized ITA method.

2.4 Classical Forms of Task Analysis of Air Traffic Control

A project sponsored by the European Commission dealt with ‘The Role of Human in the Evolution of Air Traffic Management (RHEA). In the scope of this project, various controller task analyses were reviewed, including a controller job description method which was developed by a task force under the auspices of the EATCHIP Human Resources Team (EATCHIP, 1996). This job description method delineates the importance of cognitive processes in ATC.

One of the major conclusions of this part of the RHEA Project (NLR, 1997) is that the results of task analyses are dependent on the methods used. However, a list of partially overlapping functions and sub-functions which ATCOs have to fulfil while doing their job could also be delineated. In this context, the term ‘function’ was used instead of ‘task’ so as not to distinguish between functions carried out either by humans or machines.

The approach used in the RHEA Project did not, however, account for the link between functions and goals which is usually the basic assumption of any action-oriented task analysis. This sometimes made it difficult to evaluate the role of different functions and processes.

As the analysis conducted by Cox (1994) was one of the major sources for the RHEA Project and because of the fact that this Hierarchical Task Analysis (HTA) corresponds closely to action-oriented approaches, the Cox analysis will be used as a recent reference model of behaviourally-oriented task analysis. Another advantage of the Cox analysis is that, based on interview data, first inferences on the cognitive processes were added to the hierarchical task decomposition.

One of the major goals of the current ITA approach is to combine a hierarchical breakdown of tasks with a direct representation of the cognitive processes taking place to conduct the different activities and the cognitive structures involved in ATC. This goal was achieved by orienting the cognitive interview on the sequence of tasks at a working position and to extend the cognitive interview by a method which enables the reconstruction of flight progress, as well as interviewing the controller about his/her plans, anticipations, decisions and strategies according to the actual situations which appeared in the observational interval.

2.5 Cognitive Task Analysis of Air Traffic Controllers

CTA, up to now, can be viewed as an unsystematic collection of different methods drawn from different areas of cognitive psychology and cognitive sciences to throw light on the cognitive processes and structures involved in the conduct of tasks such as ATC. As mentioned earlier, the selection of methods is guided merely by the preferences and capabilities of the different research groups and not by the methodological guidelines to select methods for task analysis.

This is also stated by Seamster, Redding and Kaempf (1997) who served as pioneers in the area of CTA of ATC.

The CTA and job descriptions of ATCOs which have been conducted up to now were concerned with the identification of cognitive core tasks and cognitive supplementary tasks of ATCOs and with the problem of maintaining situational awareness.

The different task analyses have already pinpointed a variety of different cognitive tasks performed by ATCOs. Even the non-cognitively-oriented task analysis by Cox highlights the importance of cognitive aspects in ATC. Cox lists eight different cognitive tasks (planning, decision-making, reasoning, monitoring, memory and recall, situational awareness/getting the picture, attention/perception, use of prescribed procedures). On the other hand, he only identifies four observable tasks (Flight-Progress Strip (FPS) activity, communication, overt information acquisition and operation of other controls).

The 'Model for Task and Job Descriptions of Air Traffic Controllers' (EATCHIP, 1996) lists two cognitive core tasks and various cognitive supplementary tasks as follows:

<u>Cognitive Core Tasks</u>

- To maintain situational awareness,
- To decide on control actions;

<u>Cognitive Supplementary Tasks</u>

- To check technical equipment at work position,
- To build up mental picture of traffic situation,
- To handle and process Flight-Plan (FPL) information,
- To update working knowledge.

A list of supportive tasks which also include cognitive activity.

Even the behavioural tasks have a strong cognitively-oriented component, such as to provide separation, give pilots all the relevant information and provide technical ATM as well as assistance to an a/c in unusual situations; these are not possible without a huge amount of cognitive action undertaken by the controller.

CTAs in the very sense of the word have repeatedly been conducted by Redding and Seamster. The major approach they used to ascertain the cognitive structures of ATCOs was to compare experienced controllers and novice controllers. In spite of the fact that novice and experienced controllers often differ not only in their experience but also in their basic beliefs and in their personality because of different age structures, the expert/novice paradigm is one the most powerful approaches which may be used to throw light onto the knowledge structures of human beings. The main results of the Seamster and Redding analysis are summarized below. The basic tasks of an en-route ATCO which emerged from CTA combined with videotaped observations were as follows:

- Maintain situational awareness (this is defined as maintaining understanding of current and projected positions of a/c in the sector to determine events that require controller action);
- Develop and revise sector control plan (develop and revise a plan for controlling the sector which is current and comprehensive and can handle contingencies);
- Resolve a/c conflict (evaluate potential conflicts and implement means to avoid them);
- Re-route a/c (change a/c routes in response to requests or situational considerations);
- Manage arrivals (establish sequence and routing of a/c for arrival at an airport);
- Manage departures (maintain safe and efficient departure flows integrated with other sector traffic);
- Manage overflights (maintain safe and efficient overflights and integration of overflights with other sector traffic);
- Receive handoff (accept, delay, or deny handoffs);
- Receive pointout (assess and accept or decline pointout from another controller);
- Initiate handoff (transfer a/c radar identification and radio communications to the receiving controller);
- Initiate pointout (initiate and complete pointout of a/c to the receiving controller);
- Issue advisory (provide information update to a pilot or another controller);
- Issue safety alert (provide mandatory safety warning to a pilot).

Seamster et al. depict the knowledge structure of en-route controllers. This so-called expert mental model of en-route ATCOs is illustrated in Figure 2 of the current report. As the knowledge structures were not in the focus of the task-analysis method which follows in the next section, this result from the Seamster and Redding Working Group (WG) may be used as a reference for the knowledge structure of en-route ATCOs.

SECTOR MANAGEMENT		
SECTOR TRAFFIC EVENTS	**AIRCRAFT DATA**	**SECTOR CONTROL PLAN**
A/C entering sector	Altitude	Primary long-term plan
Potential conflicts	Location	Backup primary long-term plan(s)
Ongoing events	Traffic type /route	Primary short-term plans
Requests	Time and next fix	Backup short-term plan(s)
Events nearing completion	A/C speed	
	Assigned restrictions	
	A/C characteristics	
	Onboard equipment	
	Unusual situations	
CONDITIONS		
AREA AND SECTOR FACTORS	**WEATHER FACTORS**	**CONTROLLER FACTORS**
Situation in sector	Thunderstorms	Traffic volume/complexity
Situation in area/adjacent sector	Turbulence	Sector equipment status
Staffing factors	Icing	Personal factor
	Upper winds	
	Temperature	

PREREQUISITE INFORMATION	
SECTOR AIRSPACE	**PROCEDURES**
Geography	ATC procedures (applicable to prioritisation)
En-route structure	Sector-specific procedures
Published arrivals, departures, approaches	General techniques/strategies
Special use airspace	Sector-specific techniques/strategies
Topography	
Sector traps or hot spots	

Figure 2: Expert Mental Model of En-route ATCOs (drawn from Seamster and Redding, 1993)

In addition to their analysis of the knowledge structure of ATCOs, Seamster, Redding and Kaempf (1997) report on process-oriented analyses.

They analysed the decision-making of ATCOs in prescribed scenarios, and extracted and interpreted seven major cognitive tasks as follows:

- perform situation assessment,
- recognize significant events,
- monitor progress,
- prioritize scanning and actions,
- resolve conflicts,
- direct traffic for sequencing,
- manage workload and organize tasks.

In addition to these basic cognitive tasks, they stress that high-level cognitive activity is necessary to perform ATCO tasks successfully. In addition to the management of workload, they have to support the memory in actively acquiring new information and in planning ahead. The latter is related to planning strategies and the anticipation of future events. A prescribed time horizon of planning and some kind of mental simulation are therefore necessary.

The 'Model of the Cognitive Aspects of Air Traffic Control' (EATCHIP, 1997) enables these basic processes to be put into a kind of process model. Based on this model the current ITA method has been developed. The major objective is to structure the different process components and relate them to one another, while, at the same time, relating them to observable behaviour.

2.6 Limitation of Isolated Approaches

ATC is based on a huge amount of different skills. There are different cognitive skills, which allow problem-solving on a knowledge-based level, planned action on the rule-based level, and quick response to the situation on a skill-based level. This knowledge does not only include the sector management strategies, but also the handling of the ATC equipment. ATC is also an interactive task which makes it necessary to use communication skills, group monitoring skills and teamwork. This brief list shows that it will be impossible to use one specific method to derive a comprehensive picture of the ATCO's job and tasks. Consequently, Seamster et al. (1997) conclude that results from task analysis are always dependent on the methods employed.

In addition, the considerations regarding highly automated actions which were put forward in the first part of this report (see Chapter 2.3) again demonstrate the limitation of the cognitive analysis method. On the other hand, observational techniques and even observation with subsequent interviews (observational interview methods), as conducted by Cox, allow a structural breakdown of the tasks, but they do not take into account the complex processes which are necessary to conduct ATC. Even modern action-oriented task analyses break down the processes into one linear sequential structure. Complex processes are therefore difficult to analyse using the traditional approaches.

The list of arguments which show that isolated methods will result in biased and often imprecise task descriptions can be enumerated at length. However, one has to consider that each method poses load on the controllers under observation and on the observers, and may cost much in the way of time and money until results emerge. An integrated method should therefore be developed which overcomes the weakness stated by Seamster et al. (1997). Their description of the state-of-the-art of CTA claims that some results were only obtainable in the research context of university projects conducted on a very long time scale. The current approach tries to follow the line of Redding’s ITA methodology to account for the fact that different methods will reveal different results and that only a multi-level approach will enable the controllers’ cognitive tasks to be defined.

One of the major weaknesses of the CTA method is the fact that most results are based on the expert-novice paradigm. CTA is characterized by Ryder and Redding as a method which addresses expertise, especially the knowledge structure and information processing strategies involved in task performance of experienced controllers. This kind of task analysis contrasts at first glance with the traditional task-analysis methods.

However, goal-oriented task analysis has replaced traditional task analysis in many areas. For example, Endsley and Rogers (1994) used a goal-oriented approach to study situational awareness. In line with this approach, the observational methods of the current ITA were drawn from goal-oriented task-analysis methodology. The different task-analysis techniques and methods from which the methods of the current ITA were selected will be described in the following chapters.

3. TASK-ANALYSIS METHODS

As methods of CTA are less well-known, the following chapter will give a brief overview based on a review of the methods outlined by Seamster, Redding and Kaempf (1997).

Only a few years ago, in 1995, David Hopkin stated that ‘It may be more difficult to include cognitive tasks except by implication, particularly cognitive tasks with no overt activity at all, such as a controller deciding after appraising a traffic scenario that the best course is to take no action’. In the same passage: ‘Only when the full functionality of the task and the equipment are considered in detail, does the complexity emerge, whereupon the provision of a comprehensive task analysis begins to seem a much more ambitious and daunting undertaking’ (Hopkin 1995). These remarks clearly show the importance of an integration of cognitive elements into the task analysis.

3.1 Methods of Cognitive Task Analysis

The methodology of CTA is a rather recent undertaking. Consequently, there are no standardized tools which enable a CTA of ATC or a related area to be conducted using a pre-formatted system. On the other hand, fruitful results have been obtained as mentioned above by addressing cognitive processes in the course of ATC by means of techniques drawn from cognitive psychology and cognitive sciences. Some of those techniques are more suitable for elucidating cognitive structures, while others are more suitable for demonstrating the cognitive processes of ATC.

In their 1997 review of applied cognitive task analysis in aviation, Seamster, Redding and Kaempf define CTA by two functions:

- First, CTA identifies and describes the cognitive structures and processes, the underlying job expertise, and the knowledge and skills required for similar job components. CTA characterizes the learning process and the conditions which best facilitate learning;

- Second, CTA delineates the mental processes and skills needed to perform a task at the expert level and the changes in knowledge structure and processing during learning and skill development. CTA determines optimal cognitive structures and processes identifying knowledge, structural knowledge, automated skills, representational skills, decision-making and problem-solving tactics, and high-level strategies (cf. Seamster et al. 1997, p. 4).

As can be seen from this definition, there is some bias in favour of an expert-novice comparison.

In addition, the overview includes almost all relevant methods of CTA. Five different categories are outlined below:

(1) The first category deals with cognitive interviewing methods, which comprise questions and probes designed to elicit information about mental processes underlying routine job-performance or performance in critical situations.

(2) The second group of CTA methods concerns the reporting methods. These methods of introspection analyse verbalizations in conjunction with the individual's behaviour and are based on thinking aloud before, during or after working on a problem or performing a task.

(3) As a third category, team communication methods are outlined.

(4) Additionally, diagramming methods have been included. They show how concepts and knowledge are related.

(5) More sophisticated psychological scaling methods enable a picture of representations based on psychological distances to be reconstructed. The standard techniques in psychological scaling are based on rankings or pair comparisons of situations, events, concepts, principles, rules and problems.

Cognitive Interviews

Cognitive interviewing methods include structured interviews and methods of goal-means-analysis, e.g. the 'PARI' method which focuses on the Precursor, Action, Result, Interpretation steps of problem-solving by structured interviews. Seamster et al. propose a simplified PARI method which is based on task-specific problem-solving.

Another method of the cognitive interview family is termed 'critical decision method'. This technique was developed by Klein, Kelderwood and McGregor (1989). It has much in common with Flanagan's critical incident technique of classical task analysis. The critical decision method focuses on an incident experienced by an expert. Interview questions are put 'to elicit the expert's decision strategies, perceptual discriminations, pattern recognition, expectancies, cues and error' (Seamster et al. 1997, p. 69).

Standard cognitive interview techniques can also be derived from witness research. This area of psychological research focuses on the credibility of eye-witnesses (often children) and asks how biases in their reports can be avoided. Cognitive interviewing to increase the match between report and reality uses techniques such as context reconstruction and memory cues; it instructs the individual to report in a free manner, uses open or specific questions to obtain detailed and more complete descriptions, reverses the order of events and changes perspectives. These techniques have partly been included in the cognitive interview and the flight-progress reconstruction interview.

Verbal Reports

Verbal reports use audio or videotaped descriptions of the controller's action based on actual, past or future performance. Recordings of past task performance are often used to assist memory. These reconstruction methods have been used in many domains of psychology. The main advantage is that the verbal report and the self-observation do not interfere with the ongoing activity. The reconstruction method has the disadvantage of being liable to memory biases.

Shadowing the ongoing activity by a second controller is another variation of the verbal protocol method. The primary focus of the verbal protocols are cognitive processes in the course of action. Since a major problem in the traditional task-analysis method for ATC is accounting for the cognitive processes, the verbal protocol methodology appears to be the main candidate to fill the gap between the results of different CTAs and the classical task-analysis results in ATC.

As Seamster et al. correctly noticed, protocol analysis is a somewhat time-consuming process but it can nevertheless be applied in the context of team communications.

Team Communication Methods

A close link between CTA methodology and Crew Resource Management (CRM) / Team Resource Management (TRM) can be obtained by using the team communication methods. In most cases, various types of protocol analysis have been used to study communication among team members. Sociographic methods may also be employed to graphically depict:

- direction,
- frequency,
- directness of communication.

In addition, analyses of frequency, time pattern and pitch as non-verbal communication can be recorded and analysed using computerized techniques.

Diagramming Methods

Diagramming methods are presented in the context of CTA in connection with guided problem-solving. While solving problems and thinking aloud, the controller or subject matter expert has the opportunity to graphically depict the important decision points and concepts. Subsequently, the single steps are named and linked by arrows. These graphics can be analysed either by psychological scaling analysis or more qualitatively.

For a qualitative analysis, the use of a mind map (e.g. Beyer, 1993), which draws a picture of the concept and sub-concepts involved, may be useful as a supplementary method.

Diagramming can also be used to obtain a first appreciation of the organization of a specific ATC sector. Controllers can easily note down graphically the main traffic flow and the critical crossings for the traffic flow beside the conflict areas in the airspace. Asking the controller to draw a simple diagram of the sector is part of the ITA.

Psychological Scaling Methods

Ratings, sortings and other psychological scaling methods can be used to analyse the relationships of different constructions. A traditional but rarely used technique drawn from the psychology of personal constructions is the Repertory-Grid Technique used by Kelly (1955) during the fifties. This technique enables the main concepts and structural knowledge of ATCOs to be deduced.

Psychological scaling methods such as rating the proximity between two concepts or events and sorting them according to their closeness enable coefficients of distance to be computed. From these psychological distances, one can deduce the structure of the expert's knowledge. These methods are not very useful for depicting process aspects of the controller's action.

Other Methods

Finally, error analysis and the analysis of Goals, Operators, Methods and Selection rules (GOMS analysis) (cf. Seamster et al., 1997) should be mentioned. While error analysis is quite well known, the GOMS analysis corresponds to the goal-oriented task analysis. Goals are broken down into sub-goals which have to be achieved. Basic operators are identified and sequences of operators or procedures (methods for accomplishing a sub-goal) are depicted. In addition, selection rules are given for those cases in which there is a choice amongst different procedures the user might select. This method may be used in the case of given problem structures and can even be used to construct computer models of simple action.

3.2 Methods of Action-oriented Task Analysis

According to the model on cognitive aspects of ATC, plans, anticipations, goals and rules determine the activity of an ATCO to a very large extent. Action-oriented task-analysis methods conform with this assumption because their major objective is to analyse tasks based on their goal-oriented hierarchical task structure. Action-oriented task analysis attempts to evaluate the opportunity of the individual to select self-set goals and to determine these goals. Thus, freedom of action, freedom of decision-making and the individual responsibility play an important role in goal-oriented task analysis.

Action-oriented task analysis contrasts with analytical tools used to break down and describe the tasks without evaluating the role of the different activities with respect to the plans and goals of the working person. One standard methodology within the goal-oriented task analysis is the sequential hierarchical breakdown of the job and tasks. The task analysis by Cox (Hierarchical Task Analysis, HTA, 1994) and the goal-oriented approach of CTA conducted by Endsley and Rodgers

(1994) correspond closely to the action-oriented task analysis, which has made impressive progress from theories on action regulation.

A basic advantage of action-oriented task analysis is the reliable, standardised availability of task-analysis methods. One of the major questions at the beginning of the project was which of the different methods should be used for the integrated approach with ATCOs. Annex 1 gives an overview of different action-oriented task-analysis methods and their various dimensions. The original plan was to conduct the first analysis steps in Germany and, therefore, the initial methods were drawn from the various German action-oriented task-analysis methods. As most of them addressed the humanisation of industrial work, only those which possessed a version for computer work and/or mental work could be included in the overview. All techniques can be characterised as observational with subsequent or parallel interview parts with the working person.

The so-called KABA system (contrasting task analysis of office work) (Dunckel et al.,1993) seemed to be an appropriate starting point for the analysis of ATCOs, as communication and problems of HMIs form an important part of this analysis method. In addition, the organisational background is included in the KABA system. This is suitable because different European ATC units were to be compared. This again seemed to be a major advantage of this method.

Another important feature which is assessed by the KABA procedure is the future development of the technical systems, which also plays an important role in ATC in Europe. As the overview shows, the only alternative to the KABA procedure would have been an adoption of the Task-Analysis Inventory (TAI) procedure. This activity-analysis inventory includes many aspects which are of little or no relevance to the comparison of different ATCOs' tasks or of different positions, and for the development of future ATM systems. It was decided that the KABA procedure should be enriched with additional dimensions from other methods, as some of the categories of other task-analysis methods were missing.

Thus, in the first instance, task-analysis modules with known reliability and validity for computer work were selected. The resulting modules were used to conduct first observations with en-route ATCOs. As will be described in Chapter 4, there is much information which is not dependent on the specific controller and task and which is quite generic for an ATC unit. This information can be obtained in an interview with the supervisor or one of the unit-managers. Thus, a fairly economic behavioural observation method may be constructed, derived from the action-oriented task analysis (Dunckel et al., 1993). A more detailed description of this method will be given in Chapter 5.2.

3.3 Supplementary Methods

Supplementary methods were primarily drawn from the analysis of workload and research on occupational stress. Another consideration of including supplementary methods was the possibility of comparing the current results with those from other analyses on ATC.

The synthetic strain and task analysis (SYNBA) Procedure (Wieland-Eckelmann, 1997) given in the list of action-oriented task-analysis methods (see Annex 1) was used to analyse workload and stress in a Deutsche Flugsicherung (DFS) study of German controllers (Kastner, Adgammer, Budde, Hackmann, Udovic and Vogt, 1998). This questionnaire was included in the supplementary methods in order to compare the results of the current project with the German results, and it can be used to obtain hints on how to optimise the working conditions of controllers.

An important set of supplementary methods was drawn from psychological stress analyses. This enables further levels of data such as physiological recordings to be included. An easy method of combining heart-rate recordings and behavioural observation was tested to identify stressful work periods in the course of a controller's shift. This could be used to validate results from behavioural observation and the interviews on cognitive aspects.

In order to obtain a picture of a controller's stress level, a specific version of the REST - REcovery STress Questionnaire (Kallus, 1995) was developed and tested, and a brief list referring to the quality of teamwork was also included. Practical implications of the stress-related instruments do not only concern stress levels of controllers, but they also give important hints on the optimal rostering of duty and rest periods. They can help answer the question as to what the optimal level of stress and activation for the controller is while he is doing his job. Job analyses of ATC as well as error analyses pinpoint the fact that periods of very low workload which induce monotony or boredom are important. Periods with low traffic density like night shifts in some ATC units may impose stress upon the controller by forcing him to keep awake in a situation when there is not much to do. An additional question arising in this context is how to adjust to rapid changes in workload in an optimal way. According to our observations, changes in workload are a prominent feature of almost all en-route ATC units. These changes are in many cases easy to foresee so there are several possibilities of optimising adjustment to the changing situations.

3.4 Integration of Methods

One of the major goals of the task analysis was to develop a method which could be easily incorporated into the standard operations being followed in different ATC units. The conduct of the task analysis should therefore not, as far as possible, interfere with ongoing activities. The modular conception of the task analysis is one of the features which enables the method to be adopted into the standard operations of different ATC units. The integration of methods is guided by a set of questions about the material obtained. These questions guide the analysis of this material. One of the basic results of the current project is that it is necessary to provide the interviewer/observer with the basic mental picture of what is happening. Otherwise, it will be difficult to conduct the observation and keep on track with events. Even in the interview, it is sometimes necessary to guide the controller with additional questions reverting back to the processes which the interview tries to address. This again is somewhat difficult in a case where the observer has no generic picture of the tasks within a given sector. It is therefore necessary for the interviewers/observers to be given a brief introduction into the ATC unit under inspection.

An additional method of integrating the results from different methods is to conduct a final consensual validation step in a facilitated session of all controllers and task analysts who have participated in the task analysis of the unit.

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4. DEVELOPMENT OF THE INTEGRATED TASK ANALYSIS

The current task analysis was guided by the 'Model of the Cognitive Aspects of Air Traffic Control' which was finalised in 1997 under the auspices of the EATCHIP Human Resources Domain. One of the basic assumptions of the model is that the 'miracle' of ATC can only be tackled if process components are put into the focus of the analysis. We can say that currently we are able to give a brief structural breakdown of the controller's tasks. This has been repeatedly achieved (e.g., Cox, 1994; RHEA, 1997). We also have some basic data from research on the cognitive structures of novice and expert ATCOs conducted in the Seamster and Redding WG. These approaches do not focus on the process components. The cognitive processes of ATC, especially in high traffic density, are of central importance in solving the problems of future ATM system development. Therefore, the current ITA for ATCOs focuses on cognitive processes and uses observational and supplementary methods in an integrated way to validate the results.

4.1 Top-down Processes and Action-oriented Task Analysis

The selection of the action-oriented task analysis, which views the whole working process as a kind of goal-oriented behaviour, was governed by the core role of top-down[1] aspects of ATC. On the structural side, the top-down aspects fit well into the hierarchical breakdown of the tasks of HTA. The action-oriented task analysis breaks the task down in a hierarchical and sequential way. This does not conform with the fact that a formal description of the controller's activity in an action-time diagram shows a lot of overlapping activity, which, in some instances, seems only to be manageable by conducting a complex kind of multi-tasking. Therefore, an important objective of the current top-down analysis of the controller's tasks is to explain and describe the kind of multi-tasking carried out by the controller. With multi-tasking, the question of process control takes on an increasing importance.

Summarising the implications of the top-down process specified in the model on cognitive aspects of ATC, one can say that the major objective of the current task analysis is to throw light on the processes of ATC. This process description will add important aspects to the existing analyses and will help to develop ideas on the task sharing between man and machine, it will help to integrate the cognitive processes of ATC into the tutorial systems more explicitly, and it may also assist in developing new validation criteria for future selection instruments for ATCOs.

[1] Top-down governed behaviour is determined by goals, plans and intentions of the person, while bottom-up governed behaviour is primarily determined by situational events. En-route controllers describe their action as governed by their traffic picture and their plans - thus it can be categorized as top-down behaviour.

4.2 Process-oriented Cognitive Interview

The model states that ATC is guided by hierarchically organised anticipation-action-comparison loops. It also states that this is even true for highly automised habits which re-occur in every shift. Thus, even behaviour which appears at first glance to be a situationally-determined reaction can be viewed as a cue-controlled habit. In this case, a cognitive representation of the goal to be achieved by this habit always governs the behaviour of the ATCO. This approach does not exclude situationally-elicited reflexive behaviour but views situationally-determined behaviour which is not directed towards a goal as the exception and not the rule. Of course, one has to specify the conditions under which such exceptions occur. The anticipation-action-comparison loop is depicted in Figure 3.

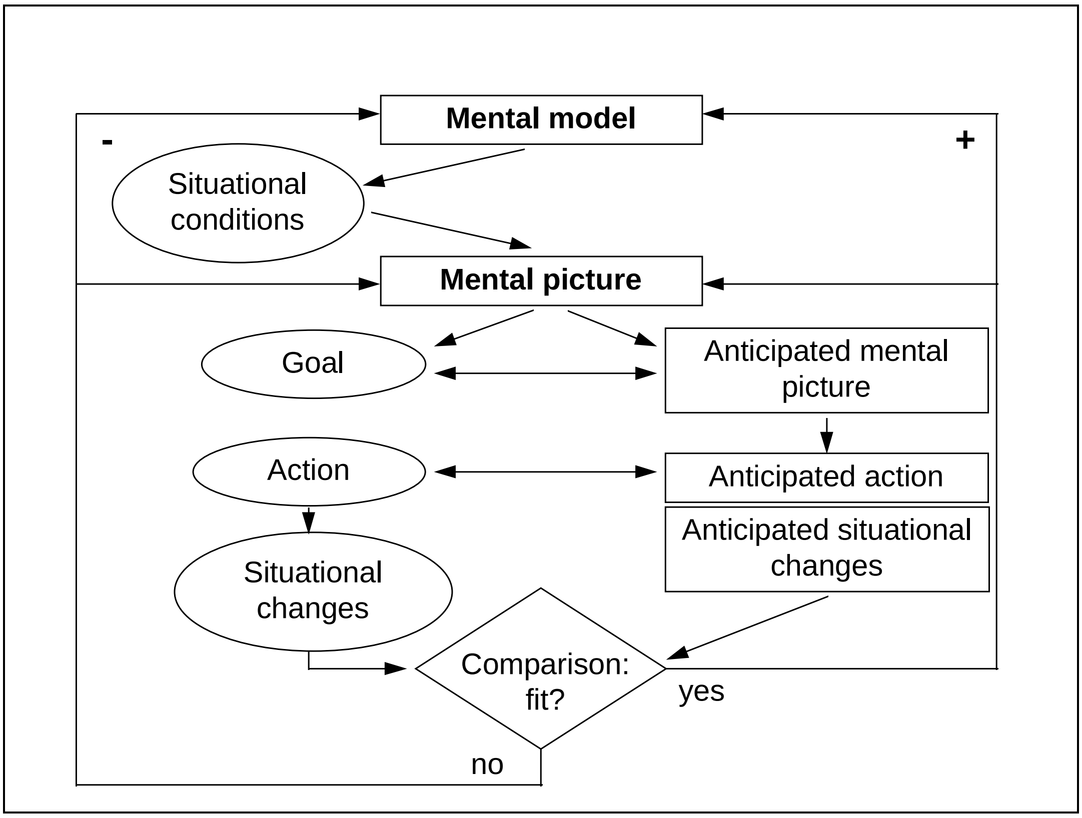

Figure 3: Anticipation-Action-Comparison Unit

This basic loop can be applied to a wide range of behaviour. Thus, on a very fine level, even the conduct of simple movements or the process of visual perception can be described by this basic unit. Of course, this implies that even perception is viewed as a kind of active process and not only as a mere reaction to environmental input. The anticipatory regulation of action makes sure that goal-oriented behaviour always takes place, even with changing environmental conditions.

Situational awareness is a higher-level process which can also be defined as the link between anticipated situational changes and the situational changes which actually take place. The whole concept of situational awareness stresses the importance of the anticipation-action-comparison loop for ATC. Again, this principle does not rule out the fact that purely reactive activities occur, but they are viewed more as an exception than as a rule.

On a more molecular level, one can describe the process of ATC in the framework given by the sequence depicted in Figure 4.

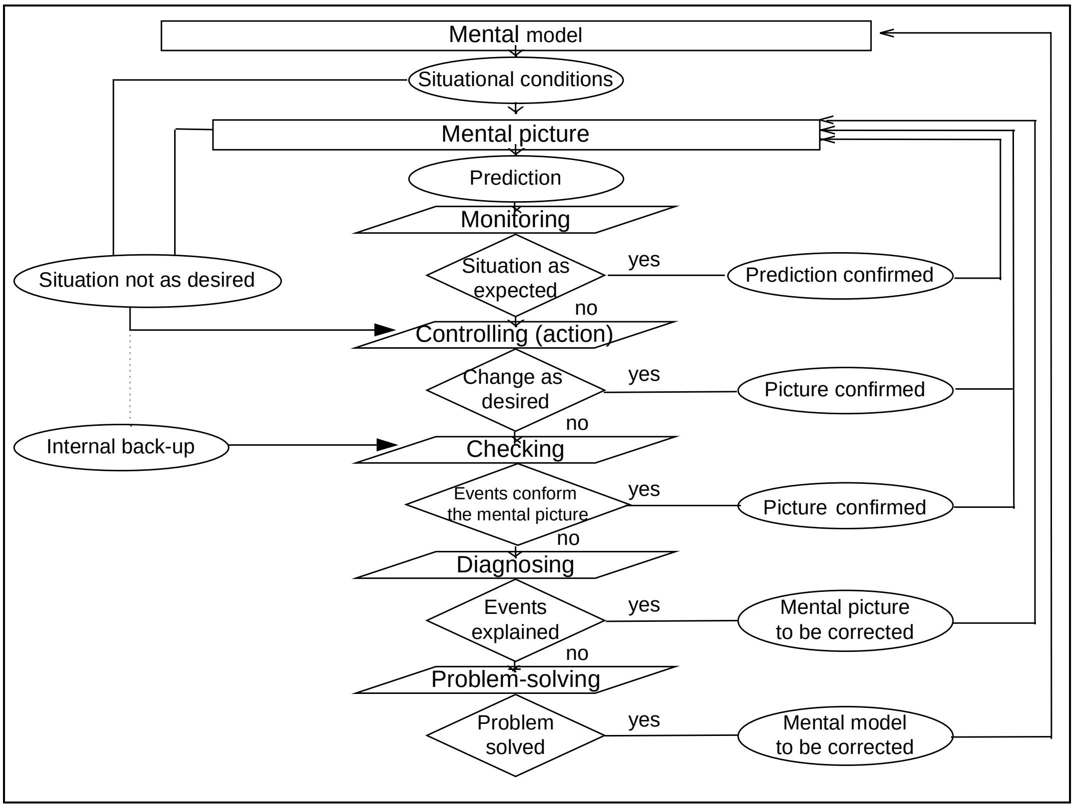

Figure 4: Basic Cognitive Processes of ATC

Figure 4 depicts the cognitive processes which appear if the controller has to deal with situations of growing complexity. The first steps can be described as processes conducted on the skill-based level and the subsequent processes can be described on a more rule-based level, while problem-solving takes place on a knowledge-based level (cf. Rasmussen, 1986). This framework has to be specified for the different tasks of a controller.

To specify the various processes conducted by the ATCO in the different phases of his activity, the cognitive interview of the current task analysis was closely oriented to the different steps an ATCO has to take in the course of a shift. As can be seen from Figure 4, it is a very important step for the controller to adjust his mental model of the sector situation to the situation at hand when he takes over the position. Based on his knowledge of the sector and on the regularly occurring changes and situational conditions, the controller is generally able to obtain a valid mental traffic picture in a very short time. On the other hand, the controller sometimes has to understand the plans and conflict solutions of his predecessor.

After having built up a basic mental picture, some kind of routine activity will take place which characterises the radar controller in general terms.

Again, these processes have to be specified. Situations of growing complexity were included in the interview because the process model of ATC predicts that in this case different cognitive processes will be set into action. What has to be elucidated is the question whether the basic processes on the lower levels still take place undisturbed or whether these processes suffer from interferences from higher-level cognitive processes.

Two of the basic categories for analysing the interview data are traffic density and traffic complexity. On the cognitive as well as on the behavioural level, the ATCO's job changes drastically with changes in traffic density. One of the major features of traffic density is that the job becomes more time-restrained. Other restrictions (airspace, military traffic, weather conditions, problems in adjacent sectors) can be viewed as further aspects which determine the controller's tasks. These have to be addressed by the cognitive interview and the interview analysis.

4.3 Linking Task Observations to the Cognitive Processes

Flight-Progress Reconstruction

Having to give verbal reports on your behaviour can drastically interfere with your activity. A large amount of training could reduce the interference between self-observation and conducting the overt or hidden action. A technique to avoid interference between verbal report and behaviour is to use reconstruction techniques. The situation is reconstructed and the verbal report can be added afterwards. This procedure is naturally biased by memory effects. On the other hand, reconstruction methods have been used in a variety of contexts ranging from research on emotions, stress and coping to the area of cognitive psychology. Thinking aloud helps in understanding cognitive processes, problem-solving and knowledge.

Hoffmann and Lenert (1992) conclude from their observations of ATCOs at AUSTRO CONTROL that controllers seem to be nearly perfect in retrieving air traffic events from their previous working periods. Even with a large time span between the report and the working period, nearly total recall was possible.

Consequently, combination of the critical decision method, as described by Seamster et al. (1997), and the reconstruction of the flight progress should serve as a useful tool to relate the results of the interviews and the task observation. Flight-progress reconstruction will help to understand the cognitive processes (planning, anticipating, monitoring, checking, diagnosing, decision-making and problem-solving) during controlling. Observations, interviews and data on psychological stress can be related to each other using information from flight-progress reconstruction.

One of the easiest methods of reconstructing the traffic events in the previous working period is to go through the FPSs or equivalent information with the controller and sort them into two categories. Category 1 consists of simple routine activity (hello-goodbye events) and Category 2 consists of a/c which made it necessary to actively co-ordinate, make a decision or resolve conflicts. A more thorough description of the procedure of the flight-progress reconstruction will be given in Chapter 5.

4.4 Methods of Identifying High Workload

Workload may be defined as objective demand of the traffic situation. The interesting question is the relationship between the workload and stress of a controller. One important mediator in this relationship is the ability of the controller to cope. An experienced controller who can use a few strategies in dealing with high workload will routinely experience less stress than a novice or on-the-job controller confronted with exactly the same traffic situation. It is therefore necessary to describe the workload/stress relationship from the controller's point of view.

In stress research, a multi-level approach which considers behaviour, physiological state, self-reports and social indicators of stress is normally used to identify stress and strain. On the behavioural level, one of the prominent indicators of stress in controllers is the frequency of Radio/Telephony (R/T) contacts (cf. Hoffmann and Lenert, 1992). Stress and heart rate are well-correlated across situations if one uses mean heart rates of different persons and mean stress ratings across traffic situations with varying complexity and traffic density. Modern techniques can obtain heart-rate recordings by means of devices used in sports medicine or ambulatory psychophysiology. We have used heart-rate recordings and frequency of R/T contacts to assess a controller's stress. These data were supplemented by simple rating scales. For further analyses, it may even be useful to include team communication into the workload/stress analysis. From our observations it emerged that with increasing traffic density, controllers tend to stick more and more to prescribed rules. This has a major impact on the team communication structure. It can therefore be concluded that analysis of team communication will help to throw light on the workload of the controllers.

Additional information to assess workload and sub-optimal conditions at the workplace can be drawn from the questionnaire methods. The SYNBA Procedure will give some additional information on the necessity of further optimising the workplace and the work environment.

4.5 Mapping the Organisational Structure of Air Traffic Control Units

Air traffic within the ECAC States is quite heterogeneous as far as the organisational structures are concerned. In some countries, ATC is part of the public administration. In other countries, ATC has been privatised. Status and salaries are also quite different across Europe. Accordingly, the organisational structures vary greatly across different states. Initial analysis of teamwork in a sample of ECAC States shows that different organisational structures are even accompanied by different kinds of team structures within Europe. As no systematic information is available, a systematic interview was adopted from the task-analysis method which pinpointed the most important organisational aspects of the ATC unit concerned.

The rostering system and the system of allocating controllers to working positions seems to be especially important in the view of the cognitive aspects of ATC. Knowing which sector will be the next one to work on or being allocated a sector on a more random basis implies different preparation. Cognitive flexibility may therefore be affected by different rostering systems.

Another aspect of organisational structure is the amount of participation and involvement related to the new developments in the control centre. This also has to be addressed by questions on the organisational background. This aspect is of special importance because aids for an approach controller, for example, may impose a different load on the en-route controller, and vice versa. Participation in different steps in the development and the establishment of new systems may therefore be very useful in achieving acceptance of new technologies. At the same time, participation can help to make new systems work as cognitive tools for the controller.

Another aspect related to the organisational background is future development in the ATC units. As new systems seem to be an inevitable factor, many controllers view their own job to be at stake. They are often quite unsure about how their vocational future will develop.

Organisational structure also encompasses the age of ATCOs. Retirement age varies drastically across Europe. As the speed of information processing is reduced with increasing age while experience grows, one can expect a trade-off between these two aspects which will come to a peak in the middle of the ATCO’s career.

Heterogeneous age in teams might affect tacit understanding and cause problems in different working styles. Thus, retirement age and age structure within the teams are another important factor of organisational structure in ATC units.

Additional aspects for teamwork could be gender and the number of on-the-job trainees.

The proportion of active work and training might also affect the working style. In many instances, active controllers serve as instructors for trainees on a part-time basis.

Information about those organisational aspects are collected in each unit by means of the organisational interview.

5. ELEMENTS OF INTEGRATED TASK ANALYSIS

This chapter gives a description of the generic methods of ITA. The material and procedure on how to conduct the different methods are provided in the technical supplement of this report as already mentioned before. The basic parts of the task-analysis system comprise the cognitive interview, material for the action-oriented task observation and the flight-progress reconstruction method. Supplementary methods concern workload/stress analysis, stress-recovery balance, heart-rate recordings and the organisational background.

5.1 Cognitive Interview

Purpose

The cognitive interview collects information on anticipation-action-comparison units at different levels of analysis and on the information processing by the controller in different task categories. Information on the cognitive structures relevant to the information processing and on the informational input and output as well as on the cognitive processes at hand is addressed by the cognitive interview. The cognitive interview analyses the differences between novice and expert controllers and, at the same time, it describes the differences between low traffic density situations and high traffic density or complex traffic situations. To avoid the risk of being too general, the cognitive interview is aimed at work in a specific sector. If possible, an actual working period is taken as a reference. However, one of the implications of this procedure is that the results will be partly dependent on the sector selected.

As the cognitive processes for different jobs appear to differ widely, only about 80% of the questions can be used for all ATC positions. 20% of the questions need to be reformulated for the relevant position. For the planning controller and the radar controller, and for en-route control and terminal area control, different versions are fully elaborated and given in the technical supplement of this report.

Description of the Interview

The interview addresses twelve topics, which are related to twelve different aspects of the ATCO's task:

Topic 1 is concerned with takeover of the position and building up the traffic picture. Questions address the kind of information that is needed to obtain the picture, the importance of the briefing by the previous controller, strategies used to build up the picture, the importance of active planning in this phase, and the criteria that make the controller say 'I take over'. Connected to this topic is the difference between paper and electronic FPSs.

Topic 2 refers to the takeover of an a/c. The question, 'From what moment do controllers start to integrate new traffic into their plans?', tries to elicit information on the planning horizon. Further questions are concerned with the mental integration of an a/c into the traffic flow, and the dimensionality of the traffic picture. In former versions of the interview, the question of whether the controller knows how many a/c are on his frequency was included. As all controllers up to now said that they did not know the exact number, and that the number is not the relevant dimension for the ATCO, this question was skipped in the current versions of the interview.

Topic 3 is concerned with traffic monitoring, which addresses the frequency of scanning the whole situation, direction of attention and the strategies used to reduce complexity. Another question is concerned with differences between peak traffic and low traffic density situations.

Topic 4 deals with decision-making and the role of assessing and estimating in the ATCO's job. The questions also aim at decision criteria and the allocation of attention to certain a/c based on prior experience.

Topic 5 covers multi-tasking and addresses its relative frequency in the controller's job. One question addresses the kind of activities that can be done simultaneously and, of course, there is the question of whether they are really done simultaneously or if they are rapidly switching between tasks. The topic of multi-tasking also addresses the opposite of multi-tasking, namely the circumstances in which the controller tends to concentrate on only one task and fade out the rest for a while, and to this, the additional question of how to re-establish the whole situation into the traffic picture was posed.

Topic 6 turns to communication with the pilots, asking for communication problems and checks on readbacks, and handling the pilots' requests.

Topic 7 addresses situations to which the controller is merely reacting, and situations which do not conform with his expectations. This area also includes situations for which mental error models exist. The controller is also asked if he is able to categorise unexpected traffic situations.

Topic 8 covers conflict situations. Questions address the recognition of conflict situations and decision-making in such situations.

Topic 9 is concerned with handing over an a/c and the conditions in which the handover becomes a non-routine situation.

Topic 10 deals with self-monitoring and the ability of the controller to re-adjust to his job after being absent. Self-monitoring also includes questions related to the actual state of the team.

Topic 11 addresses the handover of position and the question of whether the controller makes any special preparations before handing over the position to his successor.

Topic 12 covers the conditions of teamwork. The differences in working style between that of a very experienced controller and a novice assistant controller, as well as general questions regarding tacit understanding, predominate in this part of the interview.

Changes in the Interview during the Course of the Construction Phase

The interview could be shortened, and redundant questions could be skipped or put into the category of optional questions during the course of the test interviews. The test interviews showed that controllers are well able to describe the cognitive processes accompanying the different topics addressed in the interview. At the same time, it was possible to conduct the interviews in English with non-English mother tongue interviewers and interviewees. One major reason for this may be the fact that there is a communication standard in the ATC community, which ensures a basic knowledge and understanding of English, even if the subject matter becomes difficult. Of course, this would not have been possible in the case of non-motivated controllers. All controllers participated with high motivation in the interviews. Results of interviews conducted in English and German showed no substantial differences in their content. A more important factor appeared to be the ability of the controller to put his cognitive processes into words.

5.2 Action-oriented Task Observation

Purpose

The basic purpose of the task observation is to validate the answers obtained in the interviews. At the same time, the behavioural level is an important input to task description in most task-analysis systems. This source of information has to be treated as separate and important. As mentioned earlier, different levels of workload should be reflected in the way the tasks are conducted. The observational methods are also closely related to the analysis of workload and stress in ATCOs. Information concerning the organisation of work, the work position and the organisational background, is separated from the task observation and compiled into an interview to be conducted with one of the managers or supervisors of the ATC unit. The action-oriented task observations are guided by the different topics of the cognitive interview. The observation is designed to be as unobtrusive as possible and can be conducted without any direct communication with the working controller.

In order to obtain a fairly representative picture and reliable results different positions should be included in the task observation, the traffic should be at least 50-85% of the sector capacity and the observer needs a sufficient training.

Description of the System

The observational system consists of a brief set of protocol grids. The cover sheet for basic information (OB1.0) is followed by four formal observational sheets which are partially doubled in the system, and a set of rating scales. The rating scales cover aspects which could not be observed directly in an easy and reliable manner. In addition, the observations are supplemented by a post-observational interview, which is normally integrated into the flight-progress reconstruction interview. The observation sheets can be summarized as follows:

Task Units (OB2.0)

The frequency of the different task units enables the working position to be characterised both quantitatively and qualitatively. Changes in workload are reflected and differences between a pure en-route sector and a sector with several climbs and descents are reflected well in the task-unit sheet.

The tasks of the radar controller can be divided into different task units. The same is true for the tasks of the planning controller. As the tasks of planning and radar controller in many instances overlap up to the point that one controller does both jobs as long as the traffic density is not too high, the same sheet is used for both. The most important task units are listed; the sheet also includes some blank lines which can be used to put down task units which are specific for the ATC unit in question. The observer’s task is to count the frequency of the different task during eight minutes. The absolute count gives a rough impression of the traffic density and the activity of the controller. The (relative) activity profile can be used to characterise the working position.

Call Survey (OB3.0)

The next observational sheet is termed ‘call survey’. The call survey reflects number and kind of R/T contacts with the pilots. It was designed to account for the controller-pilot communication loops, and it directly allows to validate some of the results from flight-progress reconstruction methodology.

Within an interval of ten minutes, the observer notes how many FPSs are on board and his task is to put down the call signs of the a/c which are addressed by the controller during the observational period. If the observer misses a call sign, he simply notes a count in the relevant category. The categories are as follows: accept a/c, dismiss a/c, instruct/control a/c and give information; a frequency count is included for contact with the planning controller, co-ordinator and others. This sheet is only relevant for executive controllers. The call survey provides certain information on the qualitative aspects of the work, and gives an impression of how busy and less busy periods change.

Information Flow at the Workplace (OB4.0)

This sheet focuses on the information and gives an overview over the basic informational loops used by the controller.

Frequency and direction of information flow at the workplace are recorded for the different information partners. In addition, the information channels are checked within a five-minute period. Different sheets are used for planner and radar controller here.

Hand-over Survey (OB5.0)

The next working sheet deals with the traffic flow during a period of ten minutes. The observer counts the number of a/c transferred to the adjacent sectors.

The task-unit, the call survey and the information flow sheets are repeated twice. At the end of the observational period frequency ratings are given by the observer. These address physical constraints, interruptions, time pressure, information complications, etc.

Motoric Complications (OB6.1)

Physical constraints reflect problems in the ergonomy of the workplace. Physical constraints are all inadequate gesture or body posture due to the working position design (i.e. command buttons out of reach).

They are more frequent in working positions which have repeatedly been updated with new equipment over the course of time.

Interruptions (OB6.2)

The interruptions of the controller are rated on various frequency scale. As interruptions are rare, it is somewhat difficult to have them observed properly in the observational interval. The rating method was therefore selected. Ratings are given for interruptions by team-partners, controllers of adjacent sectors, pilots, the supervisor, colleagues and others, as well as for interruptions caused by technical equipment.

Information Complications (OB6.3)

Information complications were also turned from observational categories to rating categories with a frequency rating scale, simultaneity of acoustic information, interferences from loudspeakers or other frequencies, confusion of radar screen, etc., should be rated.

Other Activities (OB6.4)

This rating sheet is concerned with different kinds of activities carried out at the workplace such as talks without task relation, getting coffee or food, waiting, writing messages for colleagues or reading newspapers.

Time Pressure (OB6.5)

Time pressure, stress and co-operation are rated on seven-point frequency scales.

Co-operation (OB6.6)

Co-operation with the planning controller and co-operation with others are rated on seven-point rating scales.

Unusual Observation (OB7.0)

A blank form is provided for the recording of unusual observations.

Sketch of the Workplace (OB8.0)

In a final form, a brief sketch of the workplace should be drawn. It would show the displays and their relative size and their position, as well as the keyboards and other input devices.

Observer Rating (OB9.0)

The observer gives a rating concerning the availability of information to him/her (R/T communication, controllers' activity).

5.3 Flight-Progress Reconstruction

Purpose

Flight-progress reconstruction was included in the task-analysis system to link the interview data and the observational data via actual traffic events. Flight-progress reconstruction combines features of the critical decision method because it addresses critical events from the previous work period with verbal report methods based on a reconstruction of the situation. However, this kind of verbal report depends very much on how well the retrieval of the situation works. The basic purpose of flight-progress reconstruction is to elicit the reaction to and strategies for resolving difficult situations, and to address the problem of additional load arising from co-ordination, planning, loss of time, etc.

Description of the Flight-Progress Reconstruction Method

FPS or equivalent information form the basic material for the flight-progress reconstruction. As a first step, all progress strips are presented in chronological order, and the controller remembers each a/c and sorts them into two categories. Category 1 are routine (hello-goodbye) and Category 2 are the non-routine a/c. The non-routine a/c are arranged on the mini-pinboard or on the table. Occasionally, the controller breaks up the chronological order and may cluster the a/c according to the clustering that represents the position on the FPS board. The controller is instructed to comment on the order of the FPS.

After all the progress strips of the non-routine a/c have been re-ordered and fixed, the controller is introduced to the interview and the interviewer shortly summarises the ten questions that will be asked:

1. 'Please describe the current traffic situation and any deviation from routine or conditions which demanded additional effort.'
2. 'What went through your mind when you noticed the situation?'
3. 'What was your plan?'

4. ‘What did you do first?’
5. ‘What went through your mind at the time?’ (Optional)
6. ‘How did you reach your objective/goal?’
7. ‘Please outline the additional effort needed for attention, time, additional co-ordination and additional planning.’
8. ‘Who else was involved in the solution of the problem? Who else was affected by the situation?’ (Optional)
9. ‘What was your personal reaction?’ (Optional)
10. ‘Did dealing with this a/c interfere or affect any other processes? If so, what processes?’
11. Which technical tools were used to support the solution?

In this context, the controller usually goes through the different a/c which belong to one cluster and which have been in conflict or had to be co-ordinated.

5.4 Post-observational Interviews and Ratings

Purpose

Post-observational interviews and ratings provide an opportunity to qualify the observations more thoroughly and to take down the global impression of the trained observer. In the course of the post-observational interview, the observer’s ratings are validated by asking the controller some brief questions about the situation.

Description of the Post-observational Interview

There are prepared standardised sheets for the interview and the ratings. The observer goes through these sheets, and usually addresses his post-observational ratings first. This takes about ten minutes. It is advisable to use the last ten minutes of the observational period or the beginning of the post-observational break for these ratings.

The post-observational ratings are concerned with the characteristics of the workplace and the flow of information.

The categories of the post-observational frequency ratings are:

– motoric complications at the workplace,
– informational complications like interferences of acoustical information,
– interruptions by persons or equipment,
– activities, which are not directly related to the task,
– time pressure,
– co-operation.

Unusual observations and a brief sketch of the workplace complete the post-observational ratings.

The post-observational interview consists of a set of ratings which are answered in co-operation with the controller. It usually takes seven to ten minutes. The post-observational interview with the controller addresses biographical data and working hours, the number of duties since his last rest period, his job and task experience, variability of tasks, ratings of time pressure in the observational period, questions on how often the controller felt tensed up in the observational period and ratings on how often the controller felt idle in the observational period.

Reasons for time pressure are specified on a separate sheet. Time obligations are rated and communication problems are addressed again, such as the check of verbal information and local slang, and the planned and actual technical equipment is briefly reviewed. The post-observational interview terminates with a reproduction of the main horizontal and vertical traffic streams in the sector which should be drawn by the controller.

5.5 Stress Analysis

Purpose

One major characteristic of the ATCO’s job is the extreme variation in workload. For less busy periods, sectors are normally combined but, despite this, there are often long periods of low traffic density. During such periods, one of the major tasks of the controller is to maintain his mental picture in spite of monotonous or quiet working conditions. Quiet working conditions pose the problem of maintaining vigilance. While in medium or even moderately high traffic when the controller feels in his element, having neither to maintain vigilance nor cope with overload. Mental load sometimes moves towards the other end of the spectrum, i.e. extremely high workload with difficult traffic situations which he can only cope with by mobilising all his spare energy.

These extreme variations in stress level and related coping mechanisms are important characteristics of the job as a whole. Stress analysis is also important to advise on useful activity in rest periods, and proposals could be made on how to train new controllers to use the coping strategies developed by their more experienced colleagues. It is also possible to ascertain how technical and team assistance may help to reduce strain. This can be illustrated by a simple example. In one of our observations in which we used heart-rate registrations to assess the stress level, rather high stress levels occurred. The flight-progress reconstruction and the comments of the controller after the observational period revealed that much of the workload might have been avoided if one a/c from an adjacent airport which interfered with the whole traffic had started about five minutes later. This lack of co-ordination resulted in a heavy workload.

To supplement the stress-relevant aspects of the behavioural observation and the workload/stress ratings, recordings of physiological stress reactions and a questionnaire which assessed the cumulative effect of stress in the previous days were included in the methods of ITA.

Description of the Methods for Stress Analysis

Stress research has outlined a very wide scope of instruments to assess workload and stress. One aspect is that a multi-level approach must be used as one indicator normally does not give a valid reflection of the stress level.

An easily obtainable physiological stress indicator is heart rate. Heart rate is correlated to workload, while other indicators like electrodermal activity are more related to emotional tension.

Heart rate was recorded using a computerised version of a recording system used in sports and training monitoring. The major advantage of this system is that recording of heart rate and concomitant behavioural recordings are relatively easy, and both data sets can be analysed in direct relation to each other. The material needed is a BHL-6000-system, a standard notebook and the software package provided for the BHL-system by med-NATIC (Munich). More sophisticated systems which can record different physiological parameters including eye movement and the electroencephalogram (EEG) are available, but they require well-trained personnel and in many cases the application of these systems has to be restricted to a simulation environment which is under the total control of the experimenter.

For concomitant observations and heart-rate recordings, the system allows frequency counts on 40 different behavioural categories. The categories were drawn from the task-unit grid of the behavioural observation.

The RESTQ, which assesses the cumulative effect of different stressors, was developed within stress research and was supplemented by some questions which deal with the team quality of the controller’s team. The RESTQ enables a stress recovery profile with twelve different categories to be sketched. Three basic categories are assessed:

– general, social and emotional stress,
– occupational stress,
– recovery.

The RESTQ is available in German and English. French, Dutch, Finnish and Spanish versions exist for different research contexts. In most instances, the administration of the RESTQ is combined with the SYNBA Procedure which devises ideas on how to optimise the workstations.

The psychometric quality of the RESTQ is well-studied (cf. Kallus, 1995).

Description of the SYNBA-part D-Procedure

SYNBA is one of the standardised task-analysis systems which were screened for the development of the ITA methods, as can be seen in Annex 1. Part D is a questionnaire that deals with the assessment of conditions that can cause stress. The main areas, which are assessed by 23 items, are as follows:

- routine actions,
- freedom of selecting ways of action,
- freedom to adjust features of the workplace to personal needs,
- feedback,
- interferences,
- time obligations,
- memory load,
- co-operation.

Data on the psychometric quality of SYNBA are published in Wieland-Eckelmann, Soßmannshausen, Rose and Schwarz (1998). A large sample of German ATCOs (n=665) was studied by Kastner, Adgammer, Budde, Hackmann, Udovic and Vogt (1998) using SYNBA in the German version.

5.6 Supplementary Methods

Purpose

The supplementary methods can adjust the task-analysis system to specific problems. In its current state, the above-mentioned SYNBA has been included. One major reason is that this questionnaire was distributed to the majority of German ATCOs. It was therefore included for comparative reasons.

The organisational interview is part of the supplementary methods. Its purpose is to characterise the organisational structure of the ACC. It is included in the technical supplement.

Description of the Organisational Interview

The interview about the structure of the organisation is itself fully structured in different worksheets. It covers various aspects of the organisational features of the ACC.

These include the kind and number of work positions in the ACC, the position of the ACC within the organisation, manning, rostering system, team structure, description of different positions, internal and external information flow, recovery facilities, work environment and regulations (e.g. smoking), duration of shift and working periods, work co-ordination. In addition, the technical equipment is also addressed, including software problems, planned changes and participation issues. Supervision, responsibility for mistakes and the sectorisation are also checked in the organisational interview. If the information from this interview is available before the task observation, it is also useful for the briefing of the observers.

6. EMPIRICAL DATA COLLECTION AND ANALYSIS

6.1 Overview

The ITA system was developed by referring to an empirical basis. After basic research on the available scientific reports and a screening of the published task-analysis systems, the further development was based on results from empirical research. In order to develop the cognitive interview, 8 instructors and 24 ATCOs in different ATC units were interviewed. In order to develop the flight-progress reconstruction methods, 12 controllers were observed and interviewed. In Phase 1, the German and English versions have already been developed. Phase 2 of the project could be started without delay, and additional ITA data (observation, interview, flight-progress reconstruction) are already available. Further task analyses to finish Phase 2 of the project were conducted in November and December 1997. For the supplementary methods, 4 systematic interviews with supervisors were obtained; SYNBA results were obtained for 7 English and 6 German controllers and RESTQs have been completed by 32 controllers so far. Heart-rate registrations with concurrent behavioural observation were tested with 2 ATCOs.

6.2 Collection of Data

The different ATC units were contacted by the Human Resources Bureau - DED5 of EUROCONTROL. The normal procedure of data collection was established by a preliminary visit to the ATC unit or co-ordination by the IfB. In the case of more distant centres such as Shannon and Copenhagen, the introductory interview was scheduled together with the interviews and task observations.

In the preparatory period, the ATC units were provided with information about the model on cognitive aspects of ATC and the outline of the ITA Project was handed to them. A copy of this information is given in the Annex 2. After arranging the interviews and observations, the manager of the ATC unit or one of his supervisors agreed the dates with the IfB in Würzburg.

All ATCO’s contributed on a voluntary basis. The interviews and observations were arranged so as to have one or two interviews or observations in parallel. In most cases, two rooms for the interviews could be provided. The interviews could therefore be conducted in a relatively undisturbed atmosphere in most instances. Observations and interviews were conducted following a fixed schedule. All interviewees and controllers were informed about the main objectives of the project and instructed that they could refuse to give any information if they wanted, and that the information given would be treated confidentially. In this way, the results could not be related to any one person.

The usual procedure of data acquisition after the preparatory interviews with the ATC unit managers was a brief information session with the watch manager who normally arranged the controllers' interviews, the task observation periods and the subsequent flight-progress reconstruction. In some of the ATC units, one additional controller was allocated to the current shift to compensate for the interview time with the two other controllers.

The sequence of interviews, observations and follow-up interviews was always fed back to the watch manager. By this procedure it was possible to establish an ITA procedure which interfered only minimally with standard practices in the different ATC units.

While the interviews with instructors were conducted at the EUROCONTROL Institute of Air Navigation Services (IANS) in Luxembourg and at the Schiphol ATC Unit in the Netherlands, interviews without behavioural observation were conducted in Shannon, Maastricht and Amsterdam, and interviews plus observations were conducted in Amsterdam (one), Vienna (twelve), Zurich (seven) and Copenhagen (six).

The interviews and observations were conducted in the course of the day, starting between 6 and 8 am and ending between 4 and 6 pm.

The interviewer team consisted of five persons, four female and one male.

One problem seemed to appear repeatedly. In all first instances, the observer had to face the problem that the sectors under observation seemed to be sectors with rather low traffic frequency. The manager of the ATC unit and the watch managers were then asked to provide the controller/observer team with a busy sector. However, it proved difficult to obtain a representative sample of workload situations. While the very low traffic density situations were problematic with respect to the validity of the observation, high traffic density situations could not be observed as all who participate in the ITA Project should avoid any additional workload from the task-analysis procedure which could affect the safety of air traffic navigation. On the other hand, in the very low traffic density situation, the controller is very unlikely to show his usual boredom-avoiding behaviour. The probability is quite large that he will start to explain the situation to the observer. This, of course, is not the usual behaviour at the workplace in idle situations.

These limitations, as well as the fact that all ATCO's contributed on a voluntary basis, have to be taken into account when interpreting the data from ITA obtained by the current task-analysis system.

6.3 Documentation

Task observations were documented on the observation sheets. In the course of time, they had to be refined. Therefore, starting with worksheets from the KABA procedure which had briefly been adjusted to the tasks of ATCOs, these sheets were improved and adapted for planning controller and radar controller in an en-route ATC unit. Some of the categories were intentionally left blank, as new working positions and possibly new task units occurred which could easily be observed and had to be added if they materialised. A standard set of categories was kept, as to allow a valid comparison of different observations.

All refinements were discussed in the observer team and submitted to a test in the next developmental step. The actual observational system was reduced and restricted to those categories which could easily be observed. The steps of refinements allowed to establish a best practice observation grid by Phase 3 of the project. It is documented in the technical supplement.

In order to complete the observational sheets, it is necessary to be able to follow the R/T communication between pilot and controller. This has to be ensured before the observation starts. The observations up to then were documented by the observational sheets in paper-pencil form. Some of the observations accompanying the heart-rate registrations were documented on diskettes and could be read by the heart-rate registration software. Heart-rate registrations were documented on the hard disk of a PC and on computer diskettes. They could be read and printed by the appropriate software.

The interviews were documented on taped records. These taped records were copied to ensure data security. After being copied, the records were transcribed. Transcriptions were proof-read and subsequently submitted to qualitative data analysis. The same procedure was used for the flight-progress reconstruction records. They were also copied and transcribed afterwards.

Interviews with the managers of the ATC units or the supervisors were not tape recorded. Instead, the answers were noted on the protocol sheets of the task observational system, as were the post-observational interviews with the controllers.

Questionnaire answers were documented by the questionnaire itself. The questionnaire data were converted into ASCII-files for statistical analysis.

6.4 Qualitative Data Analysis

While the questionnaire data, physiological data and the data from the task observation were submitted to basic statistical analysis in order to compare different working positions or different ATC units, the data from the interviews were submitted to qualitative data analysis. These interview data were analysed via ATLAS-ti software.

The qualitative data analysis was guided by various questions which enabled the interview data to be structured. The controllers' answers were sorted into pre-defined categories.

Guideline for the Analysis of Cognitive Interviews

The basic questions were oriented closely towards the cognitive interview itself. In this way, we tried to prevent a severe loss of information. Nevertheless, the whole interview was scanned for answers to the analysis questions irrespective of the position within the interview.

Category 1: Takeover of position

The first group of questions was compiled with a view to clarifying the takeover of the position. Questions were:

- 'How does the controller build up the picture?'
- 'What information does the controller need for that purpose?'
- 'How important is the briefing by the previous controller?'
- 'What is the structure of the picture?'
- 'What is the purpose of the picture?'
- 'What are the criteria for taking over the position?'
- 'What conditions influence the construction of the picture (complexity of traffic, local peculiarities, personality of the controller)?'
- 'What do FPSs mean for the controller's work?'
- Miscellaneous: annotations and memos[2]

Category 2: Takeover of an a/c

- 'How does a typical takeover procedure look like?'
- 'When does the takeover of an a/c require increased attention?'
- 'How much time is planned in advance?'
- 'How is new traffic integrated into the picture?'
- 'What features of an a/c are of special importance for this purpose?'
- Miscellaneous.

Category 3: Traffic monitoring

- 'What conditions influence the direction and focus of attention?'
- 'What conditions influence the backup rate?'
- 'What are the strategies and methods to reduce or cope with mental load?'
- 'How have these strategies been acquired?'
- 'What is the difference between peak and low traffic density situations?'

[2] Like for all the categories, this category includes a miscellaneous question for annotations and memos. These annotations and memos are of special importance in the course of qualitative data analysis.

- ‘How is the concentration level affected after peak traffic situations?’
- Miscellaneous.

Category 4: Decision-making

- ‘How important are estimates as assessments for the controller’s work?’
- ‘How does the ability to estimate and assess change with increasing experience?’
- ‘What are the criteria for decision-making?’
- ‘How much of the work consists of active decisions (knowledge-based) compared to rules in decisions (rule-based)?’
- Miscellaneous.

Category 5: Multi-tasking

- ‘What kind of tasks can be handled simultaneously? (Are they automated?)’
- ‘What is the nature of multi-tasking, more simultaneous or fast switching?’
- ‘Where are the limits of multi-tasking?’
- Miscellaneous.

Category 6: Communication with pilots

- ‘What kind of communication problems occur?’
- ‘Are there expected problems?’
- ‘What hints do you have about the nature of communication/co-operation?’
- ‘What effects do communication problems have?’
- Miscellaneous.

Category 7: Data-driven behaviour

- ‘Under what conditions does the controller behave mainly reactively/bottom-up?’
- ‘What are the main objectives in these situations?’
- ‘What conditions influence how fast the controller detects that an a/c is doing something unexpected?’
- ‘What are error-prone situations?’
- ‘Are there expected exceptional cases (mental error models)?’
- ‘What are the strategies to deal with exceptional cases?’
- Miscellaneous.

Category 8: Conflict situations

- ‘How are conflicts detected?’
- ‘How are potential conflicts assessed?’
- ‘What are the criteria for solving a conflict?’
- Miscellaneous.

Category 9: Handover of an a/c

'What does the amount of attention required for a handover depend on?'

Category 10: Self-monitoring

- 'How and to what extent does the mental model of the controller change when absent from work for a longer time period and/or as he grows older?'
- 'How distinct is self-perception and monitoring?'
- 'What strategies are used when fitness decreases?'
- 'Is there team-monitoring regarding fitness?'
- Miscellaneous.

Category 11: Handover of a position

'What are the implicit rules when handing over the position?'

Category 12: Teamwork

- 'What is the purpose of communication?'
- 'Are there "shared mental models" in teamwork?'
- 'What can "tacit understanding / shared mental model" be reduced to?'
- Miscellaneous.

Filtering the Interviews by the Analysis Questions

The answers of different controllers were clustered in an attempt to obtain a basic picture of each situation. This basic picture is used to formulate a breakdown of the process of ATC in different situational conditions. For this purpose, the breakdown will delineate the tasks and sub-tasks at different levels, and, at the same time, show which processes and cognitive structures are affected. An additional category of the relevant information will be included. The breakdown will have about two to three levels which delineate the process that takes place. A process model of the actual task will be established. One can therefore expect something comparable to the analysis done by Cox. The main difference is that the focus is turned upside down. While Cox's analysis focuses on the structural breakdown of the task, the current analysis focuses on the cognitive processes. The major result will be a process description followed by a brief breakdown. Cox did it the other way around - he provided a breakdown of the task with a rudimentary process description.

Flight-Progress Reconstruction

As a first step in the analysis of the flight-progress reconstruction, the ten questions put to the controllers were used as a guide.

Analysis of Observational Data

Observational data were converted to a file which enabled the basic descriptive analysis to take place. First results will be obtained from Phase 2 of the project.

6.5 Psychometric Considerations

Some initial remarks on the psychometric data of the method will be given in the following paragraphs but as the data processing is not yet finished, the final results such as consistency of the answers, the inter-observer and the inter-controller consistency will be reported at the end of the project.

One of the most important results is that all the controllers who were interviewed in English stated that they were able to put their thoughts into English words, and that the interview questions were easy to understand. It is possible to give the interview in German as well as in English. Even an interviewer and a controller who were not English native speakers were able to communicate about the cognitive processes using the English language.

First results show that the content of the interviews and the amount of information are only slightly correlated with the language. In spite of this fact, there are differences between controllers on how far they are able to talk about the cognitive aspects of their jobs. Some of them explained very fluently how their plans and conflict-resolving strategies change with experience or with traffic density, while others were hardly able to comment on these topics at all.

The idea of developing the system in a kind of standard language, assisted by the versions of the interview in native languages, turned out to be an important step towards the development of an ITA system which can be used all over Europe. The reason why the interviews can be conducted in English is partly because many of the phrases have their origin in a highly standardised ATC phraseology.

Some other hints on the validity of the interviews can be drawn from specific questions. For all the controllers, the first interviewers asked the question as to whether they knew how many a/c were on the frequency at the time. All the controllers consistently said that they never know how many a/c are there, despite the fact that there may be only one or two. The number of a/c, therefore, does not seem to be a relevant category for the checking and monitoring of the air traffic. This is quite an important observation, as it sheds light on the kind of traffic pictures the controllers seem to have in mind. As far as other questions are concerned, there was at least sufficient consistency within one air traffic centre. Interestingly, some of the answers seemed to depend strongly on the local practices, the local organisation, the rostering system, and the allocation of controllers to their tasks.

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7. INITIAL RESULTS

From Phase 1 of the project on ITA, only some brief results were obtained. Phase 1 of the project commenced with the development of the system and guidelines to conduct the task analysis. Results with importance for the conduct of an ITA system will be summarised in the following paragraphs. A brief outline will be presented in Chapter 8. Results on task description in different en-route working positions will be presented in the Phase 2 report, which will be obtainable by mid-1998.

7.1 Cognitive Interviews

A qualitative data analysis of the cognitive interviews with the twelve instructors confirms the importance of cognitive top-down processes (cf. Rabbitt, 1979) in ATC. The most interesting aspect of the instructor interviews was that the cognitive skills needed for ATC, such as building up and maintaining situational awareness, adoption of the mental model to the current traffic situation in order to obtain a valid traffic picture, planning and anticipating, diagnosing, timing of checking and monitoring, priority-setting and other decision-making skills as well as self-monitoring and team-monitoring, are usually taught in a very implicit way.

The explicit training in cognitive information processing skills emerged as an area which can further optimise training procedures.

The interviews with controllers showed that the initial results on the validation of the model on cognitive aspects of ATC could be strengthened.

Anticipation and planning are the two core processes which enable air traffic to be managed safely and economically. This confirms the top-down approach of ATC definitively confirmed. One interesting result of the planning and anticipation is that these processes do not include the more fine-grained technical task elements. Controllers state that actual action is often decided according to an ad hoc criterion. The actual sequence of R/T communication and the actual wording is usually not pre-planned, but conducted according to habits or situational or other factors of which the controller is not aware.

Although the cognitive processes of radar controllers and planning controller/co-ordinators are closely linked, they are different. As a consequence, some of the interview questions had to be specified for the two groups of en-route controllers. The idea of using the limited capacity of the human working memory as the only critical bottleneck of the ATC process emerges as being somewhat oversimplified. There is at least one very critical feature in ATC: time management. One of the most important aspects of time management is the fact that the R/T frequency cannot be used for multi-tasking. In critical situations, controllers are very much concerned not to overload the R/T frequencies.

Another interesting result is that the takeover of the position and the time needed for this differs from unit to unit and from position to position, and is not only dependent on traffic density. As already mentioned, controllers usually do not know how many a/c are on their frequency and they are quite aware of this fact.

Another consistent finding is that handing over the position is well-prepared by every controller.

The question of how many dimensions are in the mental picture of the radar controller resulted in the unexpected number of two for many of the controllers. They state that their mental picture is very similar to the radar screen with the level information coded as an additional number. Of course, some of the controllers claim a three-dimensional picture, which seems to be necessary at least for the conduct of procedural control. An interesting implication might be that certain conflict-managing strategies may be pre-formatted by the two-dimensional picture. This will be studied further in Phases 2 and 3 of the ITA Project.

One basic difference between situations with low or medium traffic density and high traffic density appears in the sense that the more crowded the airspace becomes, the more rigid and 'law-abiding' the controller seems to be. Thus, even in advanced systems the results obtained by Sperandio (1977) could again be validated.

7.2 Task Observations

One of the first results we were confronted with is that the task observation is very complex unless the observer does not have a basic mental picture of the traffic situation/sector (cf. Hoffmann and Lehnert, 1992).

As others have already pointed out, the frequency of R/T communication seems to be an easily obtainable measure of the workload of the controller. Thus, an introduction of HF-experts in ATC or HF-training of ATCOs has to be recommended for the further application of the observational methods.

The observational methods provide us with information from samples and can be used to compute statistics. However, the observational methods in many instances do not reflect the impression which the observer receives during the observation. Some of the observational categories were therefore transferred to frequency rating scales. With these rating scales, it seemed to be much easier to obtain a valid description of the observed situation.

From this observation, the idea of recording the speech pattern of the controller with speech pattern recording devices was derived. A logoport system could compute different patterns of speech activity development (Krüger and Vollrath, 1996). The controllers' R/T communication pattern as well as further speaking activity can thus precisely be documented. The patterns reflect communication patterns, which are relevant for team work, and at the same time, the organisation of action will change the ATCO's speech patterns. At the same time, heart-rate recordings are conducted. Thus, two objective parameters which reflect strain can be drawn from these recordings (cf. Krüger and Vollrath, 1996, Zeier, 1992). These systems are recommended as a supplementary method for task observations. However, as they are still under development (Krüger and Vollrath, 1996), one has to make sure that the software tools fulfil the requirements.

In the task observation, different team communication patterns emerged.

As already mentioned in the methodological considerations, it is quite difficult to observe representative samples of sectors. Very low traffic density and very high traffic density are not suitable for conducting task observations. The different grids for task observation turned out to give complementary information on kind of dominant action, information flow, interaction with pilots and adjacent sectors.

7.3 Flight-Progress Reconstruction

One of the profitable side-effects of task observations is that they are valuable preparations for the flight-progress reconstruction interview. Without the observation, this interview is likely to be less valid.

The flight-progress reconstruction again showed that all controllers are able to reconstruct an exact picture of each FPS and the related strips and a/c. For most of the controllers, it seems to be quite easy to report on the cognitive processes based on a reconstruction of the situation by FPSs. The method enables plans, problems, solutions and the controller's state in the course of the previous control period to be inferred.

As in the case of the interview, the flight-progress reconstruction works in English as well as in German and does not need to be conducted in the native language of the controller or the interviewer.

As flight-progress reconstruction can be used off-line, it may be extended to study some specific questions such as differences between planner and radar controller, differences between different positions, and differences between novice (e.g. on-the-job trainees) and experienced controllers.

First results seem to support the view that flight-progress reconstruction is a valuable tool for linking the results from the cognitive interview to the task observation and the workload stress level of the controller.

In many instances, only 45 minutes were necessary to complete the interview. A rather interesting side-effect emerged when the planning controller and the radar controller were asked to do the flight-progress reconstruction in pairs. Some interesting results on tacit understanding and the share of mental model between planner and tactical controller can be inferred from their discussions and the differences in their views. A standard answer in this context was 'I already knew, what my planner/tactical controller was going to do', which referred to sector specific conflict solution strategies, resulting in 'smooth' and expeditious conflict avoidance. This implies that both controllers have a shared traffic picture and/or shared anticipations of future situations, which allow to 'know' what the team partner is going to do. A group flight-progress reconstruction can therefore be used to study these aspects supplementary.

Supplementary Results

It is an important fact that the brief questionnaires (SYNBA, RESTQ) were well accepted by the controllers. The results of the two heart-rate recording periods and the concomitant registration of traffic events were also interesting. The initial analysis shows differences between busy and ‘not too busy’ periods. At the same time, both records show that at the beginning of the observational period, the takeover of the position is accompanied by an increase in stress level as reflected by the heart rate.

The SYNBA procedure revealed that there was only a very small number of advisable changes in the different work positions.

8. RECOMMENDATIONS

The ITA system takes about five to six hours per controller. Interestingly, the results from the interviews and also from the observations seemed to converge after studying four to six controllers. It might therefore suffice to keep this number in mind in the future, even if statistical considerations set six as the absolute minimum for statistical analysis. Six controllers can be studied by two observers within two or three days. The time consumption and possible interference with normal work appears to be acceptable for practical application and safety aspects.

The qualitative data analysis of the interview and flight-progress reconstruction methodology is still somewhat time-consuming. Based on the results of Phase 2 of the project, those questions which strengthen the aspects of the controller's tasks common to different ACCs will be skipped in favour of the questions which can elicit information that corresponds to the particular position concerned and which differentiates between the different ACCs and equipment in the ECAC area.

While working with the ITA system, several findings indicate the need for additional research.

A basic feature of the ITA system is the fact that it consists of standardised modules which can be combined in various ways. The observers however are advised to conduct at least the cognitive interview, an observation and a flight-progress reconstruction. This would usually last three to four hours.

By its very nature, ITA will help to conduct recurrent descriptions and analysis of future ATC tasks, roles, functions and jobs. The elements and techniques of the task analysis itself have to undergo a continuous update and revision, taking into account the technical and environmental changes in European ATM. However, the basic elements for analysing human information processing in ATC will prove to be applicable even in the ATM systems of the future.

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ANNEX 1: OVERVIEW OF ACTION-ORIENTED TASK ANALYSIS SYSTEMS

Note: Codes and numbers of 'Recorded Criteria' allow direct reference to the codes of the published versions of the different task analysis systems.

RECORDED CRITERIA / ANALYSIS SYSTEM	**A. Company, Organisational Unit**			
	1. General data of the organisa-tion (TAI)	**2. Definition of the organi-sational unit to examine**	**3. Integration of the unit within the organisation**	**4. Structural data on the staff**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**		A1.00 Name of the organisational unit	A2.10 Hierarchical structure A2.20 Flow of informa-tion within the organisational unit	
JOB-ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**				
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**		ET 1) Organisational unit; name given by the organisation		
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**				
JOB-ANALYSIS INVENTORY **TAI**	1.1. Whole company 1.2. Location 1.3. Employee´s representa-tion	2.1. Nature and position of the unit within the company	2.3. Structural data on the staff: hierarchical organisation of the unit	2.3. Structural data on the staff: - number of employees in the unit, - specialisation within the unit, - etc. 3.3. features of task execution: arrangement of absenteeism
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**			3.5.1. Scope of the authority to issue directives	4.7. Miscellaneous: - salary, - share in profits/ losses

RECORDED CRITERIA / ANALYSIS SYSTEM	**A. Company, Organisational Unit** (continued) **5. Workplaces and Workflow**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	A3.10 Workplaces and work units of the organisational unit A3.20 Feature of the organisational unit A3.30 Workflow in the organisational unit
JOB-ASSESSMENT SYSTEM MENTAL WORK **TBS - GA**	D1. main levels of the psychological regulation of the job execution D2. required information input processes D3. required information-processing processes D4. required performance of short-term memory and attention D.S.D. Overview: necessary mental (cognitive) performance
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**	ET 2) Location of the workplace ET 4) Nature of the job and amount of daily work with the computer A1) During your work you have to watch several things at the same time so you have to keep a lot of information in your mind A2) You have to work on difficult tasks which need a high level of concentration and accuracy A3) The job demands routine actions and practised movements without having to think about them
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**	A2. Workplace B3. Work units processes: - get, - perceive, - work on, - move on work tools and information
JOB ANALYSIS INVENTORY **TAI**	2.3. Structural data about the staff: - types of workplaces, - working hours 3.2. Features of the hierarchical organisation and organisation of workflow 4.3. General perceptual performance: input of immediate sensory information 5.4. Observation of things, situations, behaviour; monitoring of processes, signal recording 5.5. Gaining verbal information by questioning/listening 6.6. Operating tools or machines
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**	1.2. Sensory and perceptual processes 1.3. Assessment processes 1.4. Mental effort and decision-making processes 1.5. Use of learnt information 3.5.2 Other organisational tasks 3.6 Conflicts

RECORDED CRITERIA / ANALYSIS SYSTEM	A. Company, Organisational Unit (continued)	
	6. Information and communication equipment	**7. Planned changes and participation of employees in this**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	A4.10 Hardware in the organisational unit A4.20 Software in the organisational unit A4.30 Information and communication: - equipment, - general data	A5.10 Planned changes A5.20 Participation of employees in this
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**		
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**		
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**		
JOB ANALYSIS INVENTORY **TAI**	3.2. Features of the hierarchical organisation and organisation of workflow: participation possibilities in the general organisational conditions 3.3. Features of the task execution	
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**		

RECORDED CRITERIA / ANALYSIS SYSTEM	B. Features of the Workplace	
	1. Prerequisites of the task analysis	**2. Workplace, environment and work tools/equipment**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	B1.10 Name of organisational unit and workplace, date and time B1.20 Person and working hours B1.30 Experience on the job and the present tasks	B2.10 Sketch of the workplace B2.20 Work tools/equipment
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**	E1. Necessary professional knowledge E2. Use of the professional knowledge in the analysed job E3. Further education demanded by the job	
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**		
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**	A1. Prerequisites of the analysis A1.1. Experience on the job A1.2. Experience on the current tasks A1.3. Education/training A1.4. Working hours A1.5. Working hours per week A1.6. Hours of overtime per week A1.7. Age A1.8. Sex	A2. Workplace B2. Work tools/equipment and information
JOB ANALYSIS INVENTORY **TAI**	7.1. Officially demanded and actually existing qualifications, training, job experience 7.2. Personal data 7.3. Required knowledge	3.1. Formal general conditions of the job: - employer/employee relationship, - etc. 6.1. Operation of tools, instruments, machines: technical tools, instruments, machines
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**	1.5. Use of learnt information 4.6. Arrangement of working hours	2.1. Use of tools, technical instrument and systems 4.7. Miscellaneous: - dress regulations, - legal regulations.

RECORDED CRITERIA / ANALYSIS SYSTEM	**B. Features of the Workplace** (continued)		
	3. Differentiation of work tasks	**4. Flow of information between workplace and other organisational units and workplace**	**5. Variability of tasks**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	B3.10 Protocol sheet B3.20 Task: - relative share of time, - work units. B3.30 Side task	B4.00 Flow of information workplace	B5.00 Task variability
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**	A1. Variability of the job	B4. Communication B6. Way of the task induced exchange of information	AV. Completeness of the job structure
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**	ET3) Distribution of the work on different areas		
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**	A3. Work tasks B5. Structure of the task		
JOB ANALYSIS INVENTORY **TAI**	5.0 Share of time of different actions for information input 6.0 Share of time of different actions for information output 6.1 Operation of tools, instruments, machines: duration of a work unit	3.2. Features of the hierarchical organisation and organisation of workflow: - possibilities to get information, - location of the communication, - etc. 5.2. Gaining verbal information by questioning/ listening: get verbal instructions	
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**		3.2 Various interpersonal relationships 3.4 Individual contacts	

RECORDED CRITERIA / ANALYSIS SYSTEM	**B. Features of the Workplace** (continued)	**C. Features of the Work Task**
	6. Ergonomic problems	**1. Features of the work outcome**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	B5.00 Ergonomic problems	C1.00 Features outcome
JOB ASSESSMENT SYSTEM MENTAL WORK **TBS - GA**		
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**	R5) Your work is affected by noise, dim light or extreme temperatures	
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**	B4. Impediments: negative environmental effects D2. Problems to cope with the task	B1. Outcome
JOB ANALYSIS INVENTORY **TAI**	3.5. Physical - chemical and spatial environmental conditions 5.1. Observation of things, situations, behaviour, monitoring of processes, signal recording: spatial arrangement of visual displays	6.2. Output of verbal information (speech) 6.3. Production of drawings, sketches, plans, pictures 6.4. Handling of numbers, calculations, use and construction of programs 6.5. Production of written, verbally-coded information: writing of texts
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**	4.1.2. Room climate 4.1.3. Various external work conditions 4.1.4. Workroom 4.2.1. Dangerous conditions	

RECORDED CRITERIA / ANALYSIS SYSTEM	**C. Features of the Work Task** (continued)	
	2. Features of the work assignment	**3. Features of the work information**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	C2.00 Features work assignment	C3.00 Work information - way of access
JOB ASSESSMENT SYSTEM MENTAL WORK **TBS - GA**	A1. Variability of tasks	A4.1. Necessary information A4.2. Necessary information about the function of machines A4.3. Feedback
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**	A4) The work mainly consists of short, non-complete tasks	
ANALYSIS OF PSYCHO-LOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**	B5. Structure of the tasks	B2.2. Information
JOB ANALYSIS INVENTORY **TAI**	2.2. Features of the assignment execution	5.1 Observation of things, situations, behaviour; monitoring of processes, signal recording; objects of obser-vation, situations and processes: - perception of visual signals, - etc. 5.2. Gaining verbal information by questioning/listening: - media of transmission complexity of the needed verbal information, - etc. 5.3. Reading of graphically-coded documents 5.4. Reading of documents with numbers and symbols 5.5. Reading of written verbally-coded documents
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**		1.1.1. Visual sources of work information 1.1.2. Non-visual sources of work information

RECORDED CRITERIA / ANALYSIS SYSTEM	D. Information and Communication Equipment				
	1. Hardware at the workplace	**2. Information and communi-cation equipment - training**	**3. Significant information and commu-nication equipment (software)**	**4. Hardware - ergonomic problems**	**5. Software - ergonomic problems**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	D1.00 Overview about hard-ware at the workplace	D2.00 Training and practice on information and commu-nication equipment		D4.00 Hardware - ergonomic problems	D5.00 Software - ergonomic problems
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**					
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**					
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**	B2.1. Work tools		B2.1. Work tools: - software, - operating instructions.		
JOB ANALYSIS INVENTORY **TAI**	3.7. Data and communica-tion equip-ment at the workplace			6.1. Operation of tools, instruments, machines: use of computer systems, programs	
POSITION ANALYSIS QUESTIONNAIRE **PAQ (FAA)**					

RECORDED CRITERIA / ANALYSIS SYSTEM	E. Scope of Decision-making 1. Requirements of planning and decision-making
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	E1.00 Scope of decision-making
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**	A.2.2. Repetition of actions A3. Possibility to automate the execution; extent of routine in execution A6. Possibilities to influence the work process
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**	T1) The work demands quick decisions, you are responsible for the consequences T2) You have to plan the optimal progress of your work yourself T3) The work is monotonous and offers only a small free play of action
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**	C. Requirements of action regulation C.1. Assessment of levels of action regulation C.2. Description of the level features
JOB ANALYSIS INVENTORY **TAI**	3.1. Formal general conditions of the task 3.2. Features of the hierarchical organisation and organisation of the workflow: scope of decision-making in the task execution 5.1. Observation of things, situations, behaviour; monitoring of processes, signal recording: autonomy of observation 5.2. Gaining verbal information by questioning/listening: autonomy of selection of verbal information 6.1. Operating tools or machines: - autonomy of selection of work tools and work subjects, - etc. 6.2. Output of verbal information (speech): autonomy in verbal communication
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**	1.4. Mental effort and decision-making processes 3.5.3. Control: nature of task instruction 4.3. Work structure

RECORDED CRITERIA / ANALYSIS SYSTEM	**E. Scope of Decision-making** (continued)	**F. Communication**
	2. Control (PAQ)	**1. Communication requirements**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**		F1.00 Communication requirements
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**	A1. Variability of jobs A1.3. Entrusted control tasks	A4.2.3 Way of human - machine/ computer interaction B5. Communication with customers
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**	L1) You are told how much and in which manner you have to perform your work, your work is controlled	K1) You mainly work alone K2) The work demands arrangement with others
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**	A2. Workplace A2.5. Control by superiors	
JOB ANALYSIS INVENTORY **TAI**	2.2. Features of the assignment execution 3.2. Features of the hierarchical organisation and organisation of workflow 3.3. Features of task execution: - control authorities, - feedback, - etc.	3.3. Features of task execution: requirement to arrange work with others 5.2. Gaining verbal information by questioning/listening: - control of verbal information, - etc. 6.2. Output of verbal information (speech): - number of required foreign languages, - etc.
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**	3.5.3. Supervision/control	

RECORDED CRITERIA / ANALYSIS SYSTEM	**F. Communication** (continued)	
	2. Immediacy/directness of required communication	**3. Co-operation**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	F2.10 Immediacy/directness of internal communication F2.20 Immediacy/directness of external communication	
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**	B1. Scope of the required communication and co-operation	B1. Scope of the required communication and co-operation B2. Forms of co-operative jobs
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**	R2) You get less or no feedback about the quality or quantity of your work performance	
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**		
JOB ANALYSIS INVENTORY **TAI**	3.3. Features of task execution: co-operation partners 5.2. Gaining verbal information by questioning/listening: - number of persons that have to be asked, - etc. 6.2. Output of verbal information (speech): - transmission of verbal information, - etc.	
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**	3. Relationships required by the task 3.1. Ways of communication 3.2. Various interpersonal relationships 3.3 Scope of the personal contacts 3.4. Individual contacts	

RECORDED CRITERIA / ANALYSIS SYSTEM	G. Strain	
	1. Informational complications	**2. Motor complication**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	G1.00 Informational complications	G2.00 Motor complications
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**		
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**	R3) The working conditions are bad, the progress of work is often disturbed R4) You only get inaccurate and hardly understandable instructions	R3) The working conditions are bad, the progress of work is often disturbed
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**	B4. Impediments: complications D1. Complications in action regulation	B4. Impediments: complications D1. Complications in action regulation: manual/motor complications
JOB ANALYSIS INVENTORY **TAI**	3.2. Features of the hierarchical organisation and the organisation of workflow: - availability of information, - etc. 5.2. Gaining verbal information by questioning/listening: completeness, unambiguity of verbal information 6.2. Output of verbal information (speech)	
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**		

RECORDED CRITERIA / ANALYSIS SYSTEM	G. **Strain** (continued)	
	3. Interruptions	**4. Time pressure**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	G3.00 Interruptions	G4.00 Time pressure
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**	A5. Predictability and time obligation of demands	
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**	R3) The working conditions are bad, the progress of work is often disturbed	
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**	B4. Impediments: interruptions D1. Complications in action regulation: interruptions by people D1.4. Assessment of interruptions by people D1.3. Assessment in summary: - risky actions, - additional effort.	B4. Impediments: time pressure D2. Problems to cope with the task D2.2. Time pressure
JOB ANALYSIS INVENTORY **TAI**	3.3. Features of task execution: availability of instruments/tools 3.4. Technical/organisational disturbances	3.2. Features of the hierarchical organisation and the organisation of the workflow: - time requirements, - etc. 3.3. Features of task execution: attaina-bility of the performance standards 6.2 Output of verbal information (speech): talking under time pressure
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**	4.5. Special demands: frequency of distraction	4.5. Special demands: working under time pressure

RECORDED CRITERIA / ANALYSIS SYSTEM	**G. Strain** (continued)			
	5. Monotonous working conditions	**6. Conflicts (PAQ)**	**7.Responsibility (TBS-GA)**	**8. Responsibility for mistakes (PAQ; TAI)**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	G5.00 Monotonous working conditions			
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**			C1. Contents of individual responsibility C2. Scope of the individual responsibility for results C3. Collective responsibility or performance	A1. Variability of jobs A1.4. Assigned correction tasks
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**				
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**	B4. Impediments: monotony D2. Problems to cope with the task D2.1. Monotonous working conditions			
JOB ANALYSIS INVENTORY **TAI**				3.3. Features of task execution: - consequences of mistakes for the work process, - etc. 3.4. Technical/organisational disturbances: coping with disturbances
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**		3.6.Conflicts		4.4. Responsibility

RECORDED CRITERIA / ANALYSIS SYSTEM	H. Degrees of Freedom Concerning Time	
	1. Requirement to plan one's time	**2. Time obligation**
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	H1.00 Requirement to plan one's time	H2.00 Time obligation
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**	A5. Predictability and time obligation of demands A5.1. Predictability of events that need to be acted upon	A2.3. Standby duties A5. Predictability and time obligation of demands: time obligation
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**		L2) You have to perform your tasks within a given time R1) You have involuntary waiting times
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**		B5. Structure of the task B5.4. Time regulation
JOB ANALYSIS INVENTORY **TAI**	3.3. Features of task execution: - planning span, - etc.	3.2. Features of the hierarchical organisation and the organisation of the workflow: - part of the information that has to be dealt with immediately, - etc. 5.1. Observation of things, situations, behaviour; monitoring processes; signal recording: - frequency of signals, - etc. 6.1. Operating tools or machines: - required speed of operations, - etc.
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**	1.4. Mental effort and decision-making processes	4.3. Work structure: - speed of the task execution, - etc.

RECORDED CRITERIA / ANALYSIS SYSTEM	I. Variability	J. Contact	K. Physical Activity	L. Structurability	
	1. Variability of assignments	1. Nature of the contacts to the material and social circumstances of the work	1. Freedom of body position and movements	1. Transpa-rency of the task and its conditions	2. Structurabi-lity of the task and its conditions
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	I1.00 Variability of assignments	J1.00 Contact	K1.00 Freedom of body movements	L1.00 Transparency of the task and its conditions	L2.00 Structurability of the task and its conditions
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**	AV. Completeness of the job structure A2. Variability of the job	B4. Communication B4.2. Possibility for collective non-task-related-communication	A7. Physical variability (movements, posture)		
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**				R4) You only get inaccurate and hardly understan-dable instructions	
ANALYSIS OF PSYCHO-LOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**					
JOB ANALYSIS INVENTORY **TAI**		3.2. Features of the hierarchical organisation and the organisation of the workflow: personal contacts	4.2. Posture and physical strain		
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**	4.5. Special demands: - further training, - business trips.		2.4. Degree of physical strain 2.5. Body posture/ body movement 2.6. Movement and co-ordination demands		

RECORDED CRITERIA / ANALYSIS SYSTEM	N. Advice for Structuring
CONTRASTIVE TASK ANALYSIS OF OFFICE WORKPLACES **KABA**	N1.00 Advice for structuring
JOB ASSESSMENT SYSTEM - MENTAL WORK **TBS - GA**	
SYNTHETIC STRAIN AND TASK ANALYSIS **SYNBA - GA**	
ANALYSIS OF PSYCHOLOGICAL DEMANDS AND STRESS AT OFFICE WORKPLACES **RHIA/VERA - BÜRO**	C. Requirements of action regulation C3. Suggestions to extend action regulation
JOB ANALYSIS INVENTORY **TAI**	
POSITION-ANALYSIS-QUESTIONNAIRE **PAQ (FAA)**	

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ANNEX 2: PROJECT OUTLINE

Integrated Task and Job Analysis on Air Traffic Controllers

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on behalf of the EATCHIP Human Resources Domain

Project Outline

1. Objectives

Cognitive processes guide the activity of ATCOs and therefore should be of priority in a task analysis. The most important cognitive processes of the multiple tasks of an ATCO are perception of information, information selection, information integration, planning and decision-making, and the maintenance of the mental picture of the air traffic situation. Previous task analyses on ATCOs using classical methods of job and task analysis do not take account of the cognitive aspects of ATC and the factor of cognitive multi-tasking. The cognitive processes of an ATCO are derived from behaviour analysis and an analysis of work tasks. The use of mental representation of the tasks as a starting point is missing from the classical methods.

Within the EATCHIP programme, Human Factors Section 3 of Human Resources Bureau - DED5 let a contract for a project on job and task analysis which required the mental processes in ATC to be accounted for. As a basis for task analysis, a model of the cognitive aspects of ATC was developed by the Institute for Evaluation Research in Würzburg. This model structures the most important mental processes and stresses the role of active planning processes in ATC. The model emphasizes the continuous and routine comparison of the anticipated traffic situation with the actual traffic situation. Thus, ATCOs continuously develop objectives within their mental picture of the situation and pro-active planning, based on a mental model, dominates their activities.

If the basic planning processes are stressed, the activities of an ATCO are presented differently from those which can be found using a more classical task analysis (e.g. Cox, 1994). The classical task analysis is orientated towards objective demands (to guide the machine safely and economically through a sector) and towards behaviour i.e. the observable activities of an ATCO (e. g. contact an a/c). The cognitive analysis is orientated towards the goals and plans of the ATCO (avoid a conflict between two a/c early, reserve an area for a/c with medical emergency, prepare good conditions for take over, etc.). Based on cognitive processes, the ITA unites the different approaches.

The resulting new structure of the ATCO’s task and job should be taken as the basis for an ECAC wide system for characterizing the different activities of ATCOs.

2. Procedure

The proposed task analysis integrates methods of CTA (e.g. interviews, reconstruction methods) and methods of more classical action-oriented task analysis (observations, observation interviews). The analyses will be conducted with 48 ATCOs.

Cognitive Interviews

- Lasts about 90 minutes (off-duty).
- Based on interview questions of the ‘cognitive model’.
- Covers the tasks between takeover and handover of the position.
- Covers those work-related aspects which the controller is conscious about and is able to report.

Observation at the Work Position

- Lasts about 90-180 minutes (on duty).
- Based on classical observation methods and adapted to the structure of the cognitive interview.
- Covers the tasks between takeover and handover of the position.
- Complements these work-related aspects which the controller is not conscious of (automated activities).

Flight-Progress Reconstruction

- Lasts about 60-90 minutes (after observation at work position).
- Based on recordings of the observed working period (e.g. flight strips, tape recordings, radar recordings).
- Covers the tasks between takeover and handover of the position.
- Analyses and validates these work-related aspects which the controller is not conscious of (automated activities) but can be observed.

On completion of these stages, a translation and transfer of the analysis procedure will be made for several representative ATC units in the ECAC area in order to ensure a European-wide validation of method, and provision of comparative results.

3. Deliverables

The analyses describe and structure the cognitive and operational processes of the ATCO's activity and the cognitive demands concerning different sub-tasks.

To this end, the activity of an ATCO will be hierarchically divided into sub-tasks. This 'action tree' will be structured from the perspective of explicit and implicit plans, anticipations (mental predictions) and decisions of the ATCO. The aspect of multiple action has to be considered. The results will be presented in an activity-structure diagram.

The final report will consist of:

(1) A description of the cognitive processes, structures and demands of the different sub-tasks.

(2) A chapter highlighting only the critical cognitive processes and potential sources of error.

(3) Action-structure diagrams.

The results will be presented to the examined ATCOs before they are published so that necessary corrections can be co-ordinated.

Furthermore, the project aims at the development of an ITA system, which will be translated into at least three European languages.

The task-analysis system includes:

(1) A detailed interview guideline for cognitive interviews.

(2) A guideline for the evaluation of the cognitive interviews.

(3) A parametrisation of a programme for qualitative data analysis (e.g. 'ATLAS-ti') which will allow concise presentation of the results regarding the action classes, the information processing and the cognitive structures.

(4) A guideline for observations at the workplace and an accompanying guideline for interviews.

(5) Table material to analyse the observations at the workplace.

(6) A guidance for the realisation and recording of a situational interview within the flight-progress reconstruction method.

(7) A system for the evaluation of the flight-progress reconstruction method.

4. Added Value

In addition to an improved understanding of the ATCO's activity and the demands placed upon an ATCO, the analysis of cognitive processes will show new important perspectives.

The ITA is focused on the ATCO and his/her cognitive processes. In this respect, therefore, the ATCO is given primary emphasis, and the concrete activities and technical equipment of the ATC unit are integrated secondarily. The analysis focuses the ATCO as the only constant factor through the various tasks of ATC. This procedure is especially useful for examining the processes of maintaining the mental picture of the traffic situation, the decisions in conflict situations and the planning of the traffic flow.

Three fields of application will be introduced in the following paragraphs.

4.1 Selection

ATC includes the monitoring and controlling of complex systems, decision-making in complex situations and multi-tasking. Yet these specific mental demands have not necessarily been taken into consideration by selection tools up to now. Previous task analyses only identified basic cognitive functions (e.g. working memory, spatial comprehension). These do not reflect the cognitive demands of the ATCO's job sufficiently. The ITA permits the distinction between cognitive demands of the various ATC tasks and jobs (ACC, APP, TWR). Based on those results, specific selection tools could be developed and combined. Thus, the current ITA will fulfil at least some of the recommendations of the Selection Task Force (STF) (EATCHIP, 1998a, 1998b). The results from the ITA will help to derive selection tests, which are linked to the controllers' tasks and allow to take cognitive aspects and job differences between different positions better into account.

Up to now, the cognitive abilities of an ATCO have been considered only in a general or indirect way and, on the basis of an ITA, the development of specific simulation and selection instruments with emphasis on mental structures and processes for ATC can therefore be created and optimized.

4.2 Training

An ITA might also lead to a modification of the main areas of training, especially in the more theoretical preparation. Typical weaknesses and limitations in human thinking and reasoning should be compensated by training.

From the cognitive model point of view, it is desirable to integrate planning and situation-related predictions more explicitly into the different areas of training. Cognitive processes like anticipation can easily be included into some training methods. There should be a routine testing of the self-assessment regarding own performance (prediction training).

The results of the cognitive-orientated ITA will be very useful to optimize simulation training. Here, the CTA will provide concrete situational examples.

4.3 Human-Machine Systems

An exact analysis of the ATCO’s information processing is not only helpful for the optimization of the human-machine systems and for the design of user interfaces but also contributes to the solution of a continuously emerging basic problem of ATC in favour of ATCOs.

With increasing technological possibilities, there is an increased risk that the activity of the ATCO is more and more reduced to a monitoring task. The activity of monitoring cannot always be considered as a strength of human information processing. In addition, it bears the risk that in case of equipment failure, the ATCO is unable to take over in a manual or semi-automated way. A major reason is that, while doing exclusively monitoring tasks over a prolonged period of time, the situational awareness and the traffic picture of the ATCO cannot be fully maintained. From a cognitive-oriented job and task analysis, one can deduce a more appropriate distribution of tasks between ATCOs and technology. The aim should be to transfer tasks to the ATCO that take advantage of the strengths of human information processing and compensate for weaknesses of the technological system. As a result, the technical equipment of an ATCO’s workplace will have the functions of so-called ‘cognitive tools’.

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GLOSSARY

For the purposes of this document the following glossary of terms shall apply (cf. Kallus, 1995; Seamster et al., 1997):

Action: An action is an intentional, goal-directed behaviour.

Anticipation-action-comparison unit: An anticipation-action-comparison unit is a set of information components allowing us to predict changes in the environmental input as a consequence of our own actions and our changes in position and posture.

Automated skills (Automaticity): Cognitive and/or physical activities performed fast, effortlessly, and with little or no attention nor conscious mental processing that are developed after consistent, repeated practice. Not all skills can be automated; it is usually possible if there is a relatively consistent stimulus or context and response (‘Automated skills’ does not refer to ‘System automation’).

Automatic processing: The type of cognitive processing that requires little or no conscious attention or thought. Tasks processed automatically are done rapidly and with little or no effort. Not all tasks are amenable to automatic processing.

Bottom-up process: A bottom-up process is an activity controlled by external cues and commands. This term is also used to describe behaviour which is primarily driven by incoming information.

Checking: Is one of the basic functions of ATC consisting in selecting information from a new situation in order to update the actual mental picture.

Cognition: Human thought processes and their components such as perception, memory and decision-making.

Cognitive skills: Almost all skills (and job tasks) have both cognitive and non-cognitive components, but a cognitive skill is predominantly cognitive in nature.

Cognitive Task Analysis (CTA): The framework and methods used to analyse cognitive structures and/or processes that support job performance. CTA differs from traditional task analysis in many ways, including the goals, methods used and data produced.

Cognitive Task Analysis (CTA) Methods: A combination of data collection and analysis techniques used to perform a cognitive analysis. The CTA methods include: critical decision method, diagramming method, rating method, sorting methods, team communication method, and verbal report method.

Controlling: Controlling is one of the basic functions of ATC. It is a process of intervention which includes the selection of a strategy, the allocation of time, and a decision to terminate. The ATCO directs single a/c or groups of a/c to obtain a desired traffic situation according to the principles of ATC.

Critical decision method: A semi-structured interview technique that elicits information from expert decision-makers about critical job incidents they have previously experienced. The expert is asked to recall critical incidents he has faced, and the analyst asks probe questions to elicit information about how he made decisions to handle the incident. It is a good method for determining the decision-making skills unique to experts.

Decision-making: Decision-making is one of the basic functions of ATC. It is an active cognitive process which selects one out of a set of possible courses of action. It includes a weighing-up of the pros and cons of different alternatives.

Decomposition: A structured analysis that breaks down higher level job units based on categories, such as the skills required, decision required, consistent components, task complexity, or concurrent tasks. Decomposition is useful in most types of analyses.

Diagnosing: Diagnosing is one of the basic functions of ATC. It is an active cognitive process taking place in order to assimilate new unexpected situational conditions into the actual mental picture of the traffic situation or to change the mental picture to account for the new evidence.

Expertise: Characterised by superior performance and mastery of the three phases of skill acquisition. There are a number of cognitive characteristics of expertise. Usually acquired after extensive and deliberate practice, true expertise often takes at least ten years to develop.

Goals, Operators, Methods, Selection rules (GOMS): A family of tools and techniques based on theory of the human information processor. The acronym refers to the basic components of the analysis: Goals, Operators, Methods and Selection rules. GOMS techniques are particularly useful in cases where the sequence of events is known.

Human resource management: The management of workers including primarily worker selection, job assignment, workforce planning, training, evaluation, and workplace satisfaction.

Input/Output (I/O) system: The (I/O) system is one of the four components of the structural model of the cognitive processes of ATC. It is responsible for the selection of information and the selection of responses.

Integrated Task-Analysis Methodology: A generic methodology that conducts a CTA alongside a traditional task analysis in three progressive stages of data collection and analysis.

Job: Tasks, sub-tasks, and task elements performed by an individual or team. The higher level unit of analysis often used in personal selection and assignment and work classification.

Job description: Describes the job and its purposes; the major activities, duties, and responsibilities involved; and the primary knowledge, skills, and mental and physical abilities required to perform competently.

Long-term memory: The long-term memory is one of the four components of the structural model of the cognitive processes of ATC. It stores the mental model, structured information (knowledge), information-processing routines and programmes.

Memory: A psychological construct representing the repository of knowledge in the brain. The human memory is divided into a short-term sensory store, a long-term memory and a working memory (cf. Atkinson and Shiffrin, 1968).

Mental model: Mental models are the cognitive processes/representations whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states and predictions about future system states (according to Rouse and Morris, 1986).

Mental picture: The actual mental picture of a situation represents a moment-to-moment snapshot of the actual situation based on the mental model and the actually perceived external cues. A series of mental pictures represents the actual mental model including the actual parametrisation.

Monitoring: Monitoring is one of the basic functions in ATC. It is a process of continuous or discrete comparison between the actual state of the system and the expected state of the traffic situation. Monitoring is a top-down process governed by the expected state of the system.

Multi-tasking: Performing job tasks or sub-tasks simultaneously or switching among multiple competing tasks.

PARI Method: PARI, which stands for 'Precursor, Action, Result, Interpretation', is a structured interview method particularly useful for determining procedural skills. The expert develops a task specific problem, and the analyst then asks precursor, action, result, and interpretation questions. The expert then gives the problem to another expert to solve, and that expert works through the problem with the analyst, again asking the probe questions. The data are then decomposed into cognitive procedures (steps) for performing the task.

Position Analysis Questionnaire (PAQ): A widely used technique of job analysis to develop employee selection criteria. It provides a list of standardised skills and abilities required by the job as a whole, but does not emphasise particular tasks, and is often insensitive to cognitive requirements.

Process Control System (PCS): One of the four components of the structural model of cognitive processes of ATC. It is a kind of internal evaluation system which makes sure that action takes place as planned by the controller.

Protocol analysis: The data analysis component of the verbal report method. An analysis of verbal reports of job performance or behaviour that includes a process of coding responses and behaviours in order to perform a content analysis or statistical analysis. Typically, the verbalisations or behaviours are segmented and analysed according to the types of strategies, goals, procedures used, knowledge required, etc.

Reliability: The extent to which two or more coders of data agree in their coding. It is important to establish good levels of inter-rater reliability to ensure that the coding scheme is valid and the coders are coding accurately.

Self-monitoring skill: A skill used to evaluate, monitor, and regulate one's own performance, including attention allocation, workload management, and recognition of problem areas in performance. Self-monitoring skills are a specific form of strategy.

Situational awareness: The perception of the elements in the environment within a volume of time and space, comprehension of their meaning and the projection of their status in the near future (Endsley and Rodgers, 1994). This also means the continuous extraction of environmental information and the integration of this information with previous knowledge to form a coherent mental picture and the use of that picture in directing further perception and anticipating future events. Situational awareness is established by a continuous comparison between anticipation (predicted state of the system) and environmental input (actual state of the system).

Skill: Goal-directed actions, both cognitive and psychomotor, that are acquired through practice. A skill is evaluated through performance; performance characterised by an economy of effort. A skill is linked with one or more tasks. The many types of skills include gross motor, perceptual motor, perceptual, procedural, decision-making, and representational skills.

Stress: High stress in terms of H. Selye (1982) is characterised by central and vegetative arousal, which is prolonged during a longer time period. The individual departs from his normal homeostatic equilibrium. Stress will also change information processing.

Sub-task: A distinct step or activity required to complete a task; used extensively in CTA with analyses focused on sub-tasks that are repeated across tasks.

System: A group or combination of interrelated, interdependent or interacting elements forming a collective entity. The fundamental characteristic feature of a system is the interdependence of its parts or variables.

Task: A basic unit of work with a clear beginning and ending pint, a goal, and one or more products. A task is the basic unit of analysis for both CTA and traditional task analysis. Task activities may or may not be observable.

Task element: A step required to complete a sub-task, normally used when a very detailed analysis is required.

Time horizon: The time window in which a worker anticipates and plans into the future, allowing him to plan and stay ahead of a situation.

Top-down process: 'Top-down' behaviour is behaviour governed by plans, mental models, intentions and rules.

Validity: The extent to which theories, models, or data accurately describe the phenomena of interest; or the degree to which a test or measure accurately measures that which it is intended to measure.

Working memory: Also known as short-term memory, working memory stores information currently being used or attended to. It has as a capacity of between five to nine 'chunks' of data at any one time, and data not attended to is lost within about 30 seconds. Skilled representations and mental models are active in working memory when used to support task performance.

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ABBREVIATIONS AND ACRONYMS

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

a/c	Aircraft
ACC	Area Control Centre
APP	Approach Control
ATC	Air Traffic Control
ATCO	Air Traffic Controller/Air Traffic Control Officer (US/UK)
ATLAS-ti	[Name of Software]
ATM	Air Traffic Management
BEA	*Belastungsanalyse* Strain analysis system [based on TAI]
BHL-system	[Name of HR-registration system]
CRM	Cockpit/Crew Resource Management
CTA	Cognitive Task Analysis
DED	Directorate EATCHIP Development
DEL	Deliverable
DFS	*Deutsche Flugsicherung* Germany’s Navigation Service Provider
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme
ECAC	European Civil Aviation Conference
EEG	Electroencephalogram
ET	Executive Task
EWP	EATCHIP Work Programme
FAA	Federal Aviation Administration
FPL	Flight Plan
FPS	Flight-Progress Strip
GOMS	Goals, Operators, Methods, Selection (rules)
HMI	Human-Machine Interface

HTA	Hierarchical Task Analysis
HUM	Human Resources (Domain)
IAM	Institute of Aviation Medicine
IANS	Institute of Air Navigation Services
IfB	*Institut für Begleitforschung* Institute for Evaluation Research
I/O	Input/Output
ITA	Integrated Task Analysis
KABA	*Kontrastive Aufgabenanalyse in Büro* Contrastive Task Analysis of Office Workplaces
med-NATIC	[Name of a company]
NLR	*Nationaal Lucht- en Ruimtevaartlaboratorium* National Aerospace Laboratory, Netherlands
PAQ	Position Analysis Questionnaire
PARI	Precursor, Action, Result, Interpretation
PCS	Process Control System
REP	Report
RESTQ	Recovery Stress Questionnaire
RHEA	The Role of Human in the Evolution of Air Traffic Management
RHEA/NL/WPR	[Refers to a document]
RHIA/VERA-Büro	*Analyse psychischer Anforderungen und Belastungen in der Büroarbeit* Analysis of Psychological Demands and Stress at Office Workplaces
R/T	Radio/Telephony
ST	Specialist Task
STCA	Short-Term Conflict Alert
STF	Selection Task Force
SYNBA	*Synthetische Beanspruchungs- und Arbeitsanalyse* Synthetic Strain and Task Analysis

SynBa-GA	*Synthetische Beanspruchungs- und Arbeitsanalyse - Geistige Arbeit*
	Synthetic Strain and Task Analysis/Mental work
TAI	*Tätigkeitsanalyseinventar*
	Job-Analysis Inventory
TBS-GA	*Tätigkeitsbewertungssystem - Geistige Arbeit*
	Job-Assessment System - Mental Work
TMA	Terminal Manoeuvring Area
TRM	Team Resource Management
TWR	Aerodrome Control Tower
WG	Working Group

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