

Computer Based Training On Human Factors for Ab-Initio Air Traffic Controllers

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SUMMARY

This paper presents a Computer Based Training (CBT) for "ab-initio" air traffic controllers on Memory, Perception, Cognition and Attention. The CBT called MemPAC was developed following a previous analysis performed jointly by the States of the European Civil Aviation Conference (ECAC) area which identified and characterized the need of training for ab-initio controllers.

The aim of MemPAC is to increase the ability of controllers to recognize the basic mechanisms and limitations of the cognitive processes involved in Air Traffic Control (ATC) tasks. The use of interactive exercises, video, games and examples from everyday life supports the presentation and the understanding of these matters.

INTRODUCTION

The European Air Traffic Management Programme (EATMP, Eurocontrol) began in 1990 as EATCHIP, the European Air Traffic Control Harmonization and Integration Programme, as a result of the decision taken by the European Transport Ministers. The rationale for this program was a response to commercial pressure and the solution was to find communal answers to the development and implementation of improvements for the Air Traffic Navigation Services in the European Civil Aviation Conference (ECAC) area. The ECAC area comprises 37 States of which 28 are Eurocontrol Member States.

Increase in traffic capacity together with improved safety and efficiency were and will remain the main drivers for the entire EATMP work program.

The development of the CBT on MemPAC is in line with the EATMP Human Factors Integration program. This program concentrates on the development of a harmonized and integrated human factors methodology for current and future Air Traffic Management conforming to best practice and principles in the areas of human cognition, behavior, capabilities and performance. The main objective of this program is to develop and apply human factors principles and methods for the best use of human performance and evolving technology.

We believe that, in training matters, the agreement on a program in a multicultural environment is to be adopted by consensus. Presentation of teachware such as MemPAC allows to progress towards the approval of a common training program in Europe.

The CBT on MemPAC has been developed for use at the Eurocontrol, Institute for Air Navigation Services, Luxembourg, and all official training centers in the ECAC area.

The ab-initio controllers

The ab-initio controller is a trainee air traffic controller. This trainee is selected from a pool of male and female applicants generally aged between 18 and 25 from all the Eurocontrol member states. The training program is divided between the Institute of Air Navigation Services in Luxembourg and the Maastricht Upper Area Control Centre. The training involves classroom lectures, CBT, familiarization visits to "live environment", simulation and on-the-job-training. The training is on a phased basis with continuous assessment in use. Assessment is by written and oral examination for the classroom elements of the training and instructor assessment for simulation. The training program from induction to rated, or qualified area radar controller, normally takes three years

THE APPROACH

The ATC domain embodies a large number of characteristics and issues that are difficult to present to an ab-initio controller. This includes in particular the cognitive processes involved in the management of the task.

In the initial phase of the development of MemPAC, we focused our attention on the following three major characteristics of ab-initio controllers: 1) partial knowledge of ATC; 2) limited knowledge on cognitive matters; and 3) possible origins from different European countries and cultures. These characteristics have played an important role in the design of the CBT, in particular in the modality with which information is presented to the student.

Additionally, since ab-initio controllers are not likely to have already experienced during their working life the issues addressed in the CBT, it is important to connect matters such as information processing activities, decision making, perceptive phenomena and capacity of memory to the tasks of ATC and present them in a way which continuously stimulates their professional interest.

The approach chosen to develop MemPAC, is based on two main principles: 1) a widespread use of examples and interactive exercises with an equal weight on everyday life experiences and ATC relevant task; 2) a simplification of the theories and terminology used, to teach simpler, less academic but more pragmatic models.

The theories are presented by exercises performed on the computer by the controllers. Animations, interactive exercises, video, and games have been all introduced to support, in a practical way, the understanding of specific theoretical matters, and to enable the controllers to experience, consciously, cognitive processes and improve their skills.

Finally, the choice to use everyday examples has been based on the assumption that ab-initio controllers have different cultural backgrounds. Hence, the examples are based on activities that are commonly carried out in the same fashion in many different countries. Driving a car, playing a piano, dialing a telephone number are some of the activities used as examples for showing some cognitive mechanisms and their limitations.

STRUCTURE OF THE CBT

MemPAC consists of four main Modules: Memory, Perception, Attention and Cognition. Each Module is structured into Sections. The navigation between Modules and Sections is free and under the choice of the student.

The main menu of MemPAC gives direct access to all available Modules and Sections. Each Section consists of Frames. Each Module is organized into four parts: a) introduction to the specific cognitive mechanism presented in the Module; b) presentation of daily life situations where the mechanism comes into play; c) presentation of examples of ATC tasks where the mechanism is involved; d) summary of the Module.

The system records the Modules and the Sections performed or partially performed by each student. Every time the student returns to MemPAC, the system restores the student's state of completion.

CONTENT OF THE CBT

Memory

Human memory is defined in MemPAC as a system for storing and retrieving information that is acquired through the five senses. Memory plays an important role in information processing, and because few aspects of air traffic control are self-evident, each controller relies on memory for accomplishing ATC missions. Working memory, short-term memory and long-term memory are presented in MemPAC as mechanisms that interact continuously while processing environmental information.

The Memory Module introduces the students to: 1) general concepts about memory; 2) working memory, short-term memory and long-term memory; 3) forgetfulness and how to cope with it.

An exercise on "Recall" and "Recognition" tasks is available. In this exercise, the material to be recognized and recalled by the student is a list of call signs. After the exercise, the performance of the student on each task is displayed to emphasize the greater complexity of the recalling task with respect to the recognition task.

Working Memory. Working memory is presented as the mind's sketchpad. Working memory holds active information and focuses on the products of perception. The main characteristic of working memory is the fact to be constrained by its capacity to keep no more than a few elements of information active at any single moment. Consequentially, knowing when to clear or update the working memory is a necessary skill, especially in ATC. The controller has to constantly remove information that is no longer necessary for updating the traffic situations.

An animation by cartoons on how the controller removes the aircraft when they leave the sector is available to visualize this mechanism.

Short-term memory. The short-term memory is related both to the perception of information, in a matter of milliseconds, and to its further processing and manipulation, in a matter of seconds. Short-term memory is involved in many forms of active information processing, including information manipulation, pattern matching, mental arithmetic, and mental projection of situations.

An example of manipulation done using the short-term memory is illustrated by the following exercise. The student has to memorize a meaningless sequence of letters such as "GDOIALASNRAENENR". This task is not easy. However, if the letters are rearranged alternating vowels and consonants, the sequence becomes "NARELADENIZAGRON", which is easier to memorize. Finally, the same letters are easy to memorize if rearranged as follows: "ORGANIZE AND LEARN".

Long-term memory. Long-term memory is presented as the storehouse of knowledge. There is no known limit to the capacity of long-term memory. Knowledge on the altitudes that an aircraft has to have to enter or leave a specific sector, or on ATC principles and procedures is stored in the long-term memory.

Long-term memory is presented along the following two perspectives of: 1) semantic memory or the knowledge of meaningful information, and 2) episodic memory or the memory for events in their sequence of occurrence.

The question "Who was the first President of the United States?" is the example used to illustrate semantic memory. Students generally remember that the President was George Washington, but do not remember exactly where and when they learned this specific piece of information.

Forgetfulness. Research has shown that controllers possess not only a high level of knowledge but also an well-organized memory. However, they can make errors related to forgetfulness. These errors occur simply as a function of time and of the relative importance of the information. Heavily processed information is

remembered better than information only superficially processed (Craik & Lockhart, 1972). For example, if a controller has communicated with an aircraft many times, that aircraft is more likely to be remembered than another aircraft that traversed the sector with less communication. Animations on strips are introduced to visualize this mechanism.

Perception

An important part of human behavior is defined by perception. Perception is a general term for the functions of different senses such as eyesight, hearing, and touch. While performing ATC tasks, the controller synthesizes two broad kinds of information, namely, what is known beforehand and what is being presented. A primary perceptual issue concerns the feasible compatibility and integrity between the presented information and the already known information. Successful information presentation entails correct sensing and correct perception.

The Perception Module introduces the students to: 1) a description of the perception mechanisms; 2) details about visual stimuli and auditory stimuli; 3) visual illusions and some guidance for addressing the issue.

In order to introduce how perception works a picture of a map of Europe, turned upside-down is presented to the student. Most of the time, the student does not recognize the picture. When the student clicks on it, the map is turned back in its correct position, and the enigma is solved.

Visual Perception. Most ATC information is visual. A busy controller may use both visual and auditory information, continuously. Successful perception depends on the absolute intensity of the visual stimuli as well as on their relative contextual intensities. To be perceived, visual stimuli have to be of appropriate size, duration, intensity, contrast, shape and color.

Examples of changes in color and size of visual items are useful to illustrate how visual perception can be successful and how it can failed.

Auditory Perception. As for visual perception, auditory perception, successful perception depends on the absolute intensity of the stimuli as well as on their relative contextual intensities. An example is the case of speech perception: in a noisy environment, critical information can be masked by the background noise. Generally, as the noise level increases, our ability to understand what is being said decreases.

A phrase pronounced by different non-native speakers, the effects of noisy and quiet environments on the same speech, and the echo effect, are some of the examples introduced in MemPAC to explain auditory perception and what can alter it.

Visual Illusions. During the mechanism of visual perception, a signal perceived by the eyes can be, in specific conditions, misinterpreted by the brain. This incorrect interpretation is called a visual illusion, since what is seen is not actual the reality. In the specific context of ATC, it is obvious that visual illusions can lead to dangerous situations.

The two major visual illusions introduced in MemPAC are the illusions of Muller-Layer (i.e. the line with the out-going fins looks longer than the line with in-going fins), and of Hering (i.e. the horizontal lines look bent because of the vertical lines). Both illusions are presented and described in the context of ATC.

Cognition

Cognitive principles and concepts and the related psychological theories, have been applied to ATC for nearly fifty years. These cognitive principles and concepts are: perception, attention, memory, information processing, planning, decision-making, problem solving, and communication (Hopkin, 1996).

The Cognition Module of MemPAC consists of: 1) a general introduction about human activities; 2) details about human capabilities and limitations; 3) examples of observable behavior (Rasmussen, 1983).

Information Processing. D. Wickens (1992), one of the leading-engineering psychologists, describes an information processing system where input signals are environmental stimuli perceived via a sensory system. Which stimulus is actually perceived by the information processing system depends, among other things, on the appropriate allocation of "attentional" resources. ATC can be seen as one of the standard examples of information processing tasks.

An interactive exercise on multiple tasks is presented to illustrate the allocation of attentional resources. The student has to listen carefully to a story (the main task) while pressing on the keyboard when a "random" spot is displayed on the screen (the secondary task). At the end of the story, the student has to answer a number of questions on the story. Performance is evaluated by counting the number of correct answers and of correct "hits", and results are shown to the student.

Skill-Based Behavior. Skill-based behavior occurs in highly familiar situations. Skills are highly practiced and are performed automatically, with little or no conscious attention. A large portion of the expert controller's observable behavior is skill-based: visual search, cursor positioning and command entry. Skills develop over time and become essentially automatic with intensive practice, on highly repetitive tasks.

A video on automatic activities such as driving a car is presented in this Section as well as a video on the ATC task and on the use of the equipment.

Rule-Based Behavior. Rule-based behavior occurs when well-learned procedures are executed under conscious attention. Situation assessment leads to recognition of which procedures to apply to particular familiar situations. Clearly, ATC performance is highly rule-based. It is governed by detailed procedures, letters of agreement between facilities, and so forth.

Knowledge-Based Behavior. Knowledge-based behavior is produced when existing procedures are inadequate to handle unfamiliar, rare events. In an ATC context, knowledge-based problem solving becomes necessary when there is no similar or identical problem pattern stored in the controller's memory. Knowledge-based problem solving requires time and effort, with no assurance that a solution will be found within time constraints.

A scenario in the ATC environment is proposed as an example of a knowledge-based behavior applied by the controller to manage an unusual situation: the emergency landing of an aircraft in a rate course.

Attention

The controller's attention is an essential factor in detecting and resolving ATC problems. Two models of attention currently in use assume that human information processing is fuelled by a limited supply of attention. The first model, the single-channel model (Kahneman, 1973), includes an information-processing bottleneck, which slows the processing of items after they have been perceived. The second model, the multiple resources model of attention, that follows the view that people have several different attentional capacities, which can be drawn upon in parallel by the demands of different task types (Wickens, 1992). Current thinking suggests that people use both single-channel (sequential) processing and multiple-channel (parallel) processing (Wickens, 1992a).

The Attention Module of MemPAC introduces the students to 1) the way attention works; 2) details about auditory attention and visual attention; 3) problems and failures related to attentions.

Animations related to the mechanisms of the filter of attention and of the two-channel model are presented to explain how attention works.

Auditory Attention. Auditory attention is the simplest form of attention that allows us to select our auditory perceptions. Auditory attention is diffused rather than focused on a particular point of the environment. Auditory attention is independent of the position of the body, head and ears, and works in a 360 degrees circle.

In the related Section of MemPAC, a video on a phenomenon referred to as the "cocktail-party effect" has been introduced to explain the differences between hearing and listening. Usually we can hear different voices, but we can only listen to one voice at the same time, by focusing our auditory attention.

Visual Attention. Visual attention is a sophisticated and complex capability. We cannot focus visual attention on the entire environment. The maximum width of the visual field is approximately 100° horizontal and 100° vertical. Anything beyond these limits is outside the range of our visual attention. Inside the visual field, only a restricted part, a range of 2°-5°, can be focused. In an ATC workplace, most of the visual attention has to focus on radar displays. Many studies have been conducted concerning the optimum lighting conditions for controllers in control centers and towers. Daily light environmental conditions help controllers to focus on the signal on the screen.

Videos of different radar displays and light configurations of an ATC workplace are presented in the related MemPAC. In addition, an interactive exercise on the effect of color and shapes on visual attention has been introduced to illustrate the difficulty to distinguish between them.

THE EVALUATION PROCESS

The first release of MemPAC was evaluated by ab-initio controllers of Institute of Air Navigation Services (Eurocontrol, Luxembourg). The objective of this evaluation process was to assess how much the course contributed to the improvement of the level of knowledge of the controllers.

Improvement of knowledge was evaluated using the following procedure. Before the course, the controller had to fill a questionnaire. Questions were of yes/no, true/false types, with an "I don't know" alternative. After the course, the controller had to fill the same questionnaire again.

Eight ab-initio controllers already at the simulator training level participated in the evaluation along with two "naïve volunteers" not related to ATC. Because of time constraints, the ab-initio controllers were not able to perform thoroughly the course but all of them went at least through the introduction and two modules. Table 1 presents the modules performed by the various controllers.

Results of the knowledge acquisition evaluation

Because of the limited number of questionnaires, only the results of the questionnaires are presented, without further analysis (see Fig. 1). The number of right answers after MemPAC has increased (from 135 to 184) and that "wrong" and "I don't know" answers has decreased (from 64 to 45 and from 31 to 1).

<i>Module</i>	<i>Number of persons</i>
Attention	7
Memory	6
Cognition	7
Perception	8

Table 1. Modules performed for the evaluation process

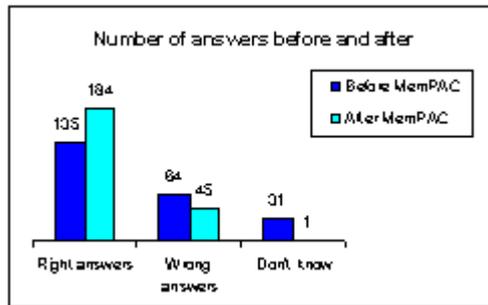


Figure 1. Results of the evaluation process

During the evaluation process, the ab-initio controllers had the opportunity to answer a questionnaire to assess their level of satisfaction with respect to MemPAC, and indirectly evaluate the quality of the product (ease of use, interest etc.) Two open questions were asked: "What did you like best in MemPAC?" and "What did you like least?"

The positive comments were mainly as follows:

- The examples used to explain the theoretical concepts are good
- The content of MemPAC is easy to understand
- The exercises are demonstrative and funny
- The English used is easy to understand
- The sound and graphical quality are very good

The negative comments concerned some students who would have liked more examples and more exercises. Further, a technical problem (which has been solved at a later stage) led to insufficient synchronization between audio and video.

In conclusion, one can say that MemPAC is useful for introducing human factors concepts in the ab-initio training of the Air Traffic Controllers, and that the CBT was appreciated by those who were involved in the evaluation of the first release of MemPAC.

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