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Human Factors Module

Learning and Skills Acquisition

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Abstract

The introduction of future ATM systems within the next ten to fifteen years will impact on air traffic control training. Using advanced computer-assisted tools will challenge the cognitive skills of the air traffic controllers. Teamwork will take on a new significance.

This document outlines current air traffic control training and takes note of how the role of the controllers will change in future ATM systems. Traditional and more recent theories of learning and motivation - HOW and WHY people learn - are examined.

In the context of the demands of future ATM systems current air traffic control teaching practices may lead to a shift away from teacher-directed training and toward learner-oriented training.

Keywords

Cognitive	Awareness	Motivation	Humanistic
Behaviour	Flexibility	Self-efficacy	Problem-based learning
Teamwork	Individual	Memory	

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1.0	30.12.1999	Released Issue (editorial changes, layout adjustments)	Where applicable

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The ATM Human Resources Unit (HUM) of the European Air Traffic Management Programme (EATMP), formerly the European Air Traffic Control Harmonisation and Integration Programme (EATCHIP), develops modules dealing with the management of human performance. This module prepared by a Project Group of the Training Sub-Group (TSG) is about Learning and Skills Acquisition (LASKA) in the context of the training of air traffic controllers. The module aims to increase awareness of the need to align air traffic control training to the changing role of the air traffic controllers in future Air Traffic Management (ATM) systems. This may lead to a fundamental change in the basic approach to controller training. A more learner-oriented and individual style of learning could be more suited to future training requirements.

Chapter 1, 'Introduction', introduces the module and explains the rationale for LASKA.

Chapter 2, 'Current Air Traffic Control Training Practice' notes that the inherent conservatism in the task of the air traffic controllers has dictated the way in which people are trained – with little change over the last fifty years. However, more and more we are detecting a specialisation in air traffic control tasks that requires a more flexible and modular approach to training.

Chapter 3,'The Changing Role of the Controllers' looks at the changing role of the controllers with the introduction of future ATM systems. Much of the material in this chapter has been developed from the work of the CAST Project (Consequences of future ATM systems for air traffic controller Selection and Training). Computer-assisted tools are becoming available which take over many of the controllers' routine tasks. This trend will continue into the cognitive domain. Current teaching practices are considered to be out of touch with the demands of modern technology and training techniques should be devised that will work with the trainees on the cognitive aspects of future ATM systems.

Chapter 4, 'Motivation – Why People Learn' considers what motivates people to learn by examining motivational theories with the emphasis on more recent findings. Human motivation is complex and the historical theories on motivation are considered limited. The conclusion identifies the appreciation of intrinsic motivators as a contributor to more efficient learning.

Chapter 5, 'How People Learn' presents an overview of some traditional (but still relevant) learning theories and takes a look at a few of the more modern theories. Three schools of learning – behaviourism, cognitivism and the humanistic approach – are analysed. The different types of memory are explored and their characteristics defined. In the humanistic approach to learning we review some practical methods to improve learning and development and state a few basic assumptions about adult learning.

Chapter 6, ‘Training for the Future‘ presents a summary of the preceding chapters and draws a number of conclusions. It proposes that air traffic control training, to remain effective in a changing environment, must consider the more recent theories that support a learner-oriented and individualistic approach to learning. Development could start on applying a learner-oriented approach to training on selected modules of air traffic control training.

There are five annexes to this document, which are self-explanatory:

- ‘References’,
- ‘Further Reading’,
- ‘Glossary’,
- ‘Abbreviations and Acronyms’,
- ‘Contributors’.

1. INTRODUCTION

This is a document about learning. It aims to create an awareness that air traffic control training must adapt to the impact that future ATM systems will have on controller practices.

This module takes a brief look at the more common theories on why and how people learn. In the context of the demands of future ATM systems, current air traffic control teaching practices may lead to a shift away from teachers-directed training and toward learner-oriented training. Future ATM systems will create entirely new functions in three broad areas of advancement: improved air-ground communications, enhanced aircraft - based systems and computerised strategic ATM aids. The controllers will be presented with new skills – cognitive skills that will impact on the way training is conducted.

Air traffic controllers have previously accepted change – from primary radar to secondary radar to aspects of automation which are taking over many of the controllers' routine tasks. This trend will inevitably continue and the job of the controllers will change from that of supervising the flow of air traffic to managing the ATM system. As advanced technology allows for the replacement of more and more of the controllers' tasks some existing skills may be down-graded or even disappear, whilst others will increase in importance, e.g. conflict detection. What will remain, however, is the overriding objective – the safe movement of aircraft in flight and on the ground.

There is an obvious change in the tools involved in the learning process, even if the methods of training have changed little. However, are the new technologies and pedagogical methods available being used to their utmost effectiveness?

Technological changes within ATM are rapid. As these changes in the new ATM systems are introduced there must be a corresponding change in attitude towards the role, function and skills of the air traffic controller. It is important that the system in which people are selected and trained for air traffic control is critically appraised. One of the fundamental areas to be addressed in such an appraisal is the learning methodology to be adopted in this new era.

Not only will new and modified skills have to be recognised but also the approach to learning itself require a fundamental change - toward learner-orientation and even perhaps the recognition of an individualised approach to learning. An insight into learning and skills acquisition will help those who are faced with the task of training people for future ATM systems to be better prepared for change.

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2. CURRENT AIR TRAFFIC CONTROL TRAINING PRACTICE

2.1 Introduction

Traditionally, air traffic controllers regard themselves as conservative in their profession. The controllers' tasks are generally rule-based with the objective of preventing collision between aircraft whilst maintaining an expeditious flow of air traffic. Within this system of rules and procedures, however, controllers develop ways of working which allow other controllers to operate in a similar manner. Each knows what their colleague is doing or is about to do. Likewise, aircraft usually fly along designated tracks so that their flight paths and relative positions can be predicted by the controllers. Change to this system meets resistance - the unknown situation is perceived as disruptive.

However, the inherent conservatism in air traffic control has dictated the way in which people are trained and from this perspective there has been little change in the last fifty years. Typically, all the theory will be covered by classroom lectures (to gain knowledge) before undertaking a series of practical exercises on a simulator in order to apply the basic operating procedures. Following this, there is a period of On-the-Job Training (OJT) at an operational unit.

The success of the training is often evaluated on the basis of the number of trainees who pass the various examinations, which are set at different phases of training, leading to final checkout.

2.2 Historical Background

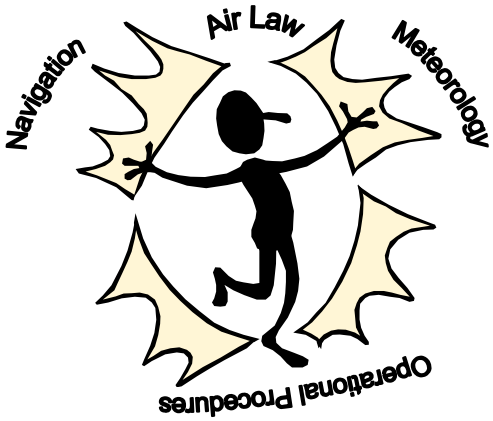
In 1948 the International Civil Aviation Organisation (ICAO) established Standards and Recommended Practices (SARPS) for Personnel Licensing in its Annex 1 to the Chicago Convention on International Civil Aviation. The Personnel Licensing Division was mindful of the importance of training and the need for a coordinated development to ensure the uniform application of the Standards. Chapter 4 of the present (eighth) edition of Annex 1 contains standards adopted by ICAO as the minimum standards for air traffic controller licensing.

In Annex 1 (ICAO), 'Approved Training' is defined as “training carried out under special curricula and supervision approved by a Contracting State”. The ICAO Training Manual (Doc 7192 – AN/857) states that “experience has shown that the necessary qualifications required for the issue of personnel licences can be more readily and speedily acquired by applicants who undergo closely supervised systematic and continuous courses of training, conforming to a planned syllabus or curriculum”.

2.3 Training Content

ICAO stipulates air traffic controllers must meet specific requirements with regard to age, knowledge, experience and medical fitness. Candidates must be at least 21 years of age (before being issued with a licence). Minimum experience requirements and standards of medical fitness are detailed in ICAO Annex 1.

All student controllers must demonstrate an appropriate level of knowledge in at least the following subjects: air law, air traffic control equipment, general knowledge of principles of flight, human performance and limitations, language, meteorology, navigation and operational procedures.



The EATCHIP Task Force on Common Core Content (TFCCC) has produced "Guidelines for Common Core Content and Training Objectives for Air Traffic Controller Training - Phase 1" (EATCHIP, 1997) detailing the subjects, topics and sub-topics to be dealt with in basic controller training.

ICAO indicates the minimum requirements but the actual content of any training plan and the time spent on individual subject varies considerably depending on the requirements of the Air Traffic Services (ATS) of any particular state.

2.4 Air Traffic Controller Training

Over a period of two to three years the *Ab Initio* or student air traffic controllers will divide their time between the training institute (for theoretical and simulation training) and the operational unit (for familiarisation and OJT). Although all training leads to the ICAO requirements for an air traffic control licence, the actual organisation of institutional and operational training will be dependent on customer needs and available training facilities. Typically, students follow an eight to twelve-week basic course that covers most of the theoretical subjects. The student (*Ab Initio*) air traffic controllers may then spend two or three months at an operational unit (supervised by the local training unit) familiarising themselves with the air traffic control environment and performing elementary tasks. On returning to the training institute the

students commence specialist training[1] for their chosen discipline (tower, approach radar or en-route control). At the end of approximately eight weeks of simulator training students return to the operational unit to start OJT. Depending on the size of the air traffic control unit, this training phase could be restricted to the function of an assistant sector controller and may last up to nine months. The final phase of institutional training (two months) will involve more sophisticated simulator exercises closely aligned to the reality of the operational unit. Ideally, on returning to their operational unit, students would then spend time at the local training unit completing transition training and pre-OJT. The final period of OJT prior to licensing can last six months to a year. The minimum experience requirements will be outlined for each air traffic control unit.

2.5 Training Media

Classroom instruction is the most popular method for teaching theoretical knowledge. Whether this takes the form of lectures, or the more participative lessons, depends on the experience of the instructor and the national culture. There are some examples of group work but the emphasis is still firmly on 'teaching'. Computer-Based Training (CBT) programmes are becoming more common and their production is being harmonised through the initiatives within EATMP. However, many existing CBT programmes are little more than electronic books. Development is now focusing on interactive CBT which gives the students increased feedback. The use of simulators (for tower and radar units) is becoming more widely accepted but they remain expensive investments restricted to larger training units. In practice, it does not seem possible to obtain the same utilisation as that obtained by aircraft simulators – many more people are currently involved in the running of an air traffic control simulation exercise than would be required for an aircraft simulator. However, advances in voice recognition technology could, in the future, reduce the need for pseudo-pilots who are presently used in the air traffic control simulators.

2.6 Phases of Air Traffic Controller Training

As shown in Figure 1 training of air traffic controllers can be divided into a number of defined phases that cover both basic and advanced training (EATCHIP (1998); see Glossary for definitions).

[1] Specialisation in air traffic control leads to more task-specific training which in turn leads to a reduction in the overall time students spend in training (from three to two years for example). To illustrate this we can outline the programme for student air traffic controllers destined for EUROCONTROL Maastricht Upper Area Control Centre (MUAC). After selection the students commence nine weeks of basic - mostly theoretical - training at the Institute of Air Navigation Services (IANS) in Luxembourg. This may be followed by three weeks of familiarisation at Maastricht. Students then complete twenty-two weeks of basic and advanced radar training gaining 140 hours experience on the simulator at IANS. This completes the Institutional Phase of their training. The Operational Phase begins with approximately sixteen weeks of transition and pre-OJT at the Maastricht training unit. It will take about one year in the operational environment to complete the first checkout. This is considered to be the end of student air traffic controller training. A further year will be spent in 'cross-over' training as experience is gained and checkouts are obtained on other sectors.

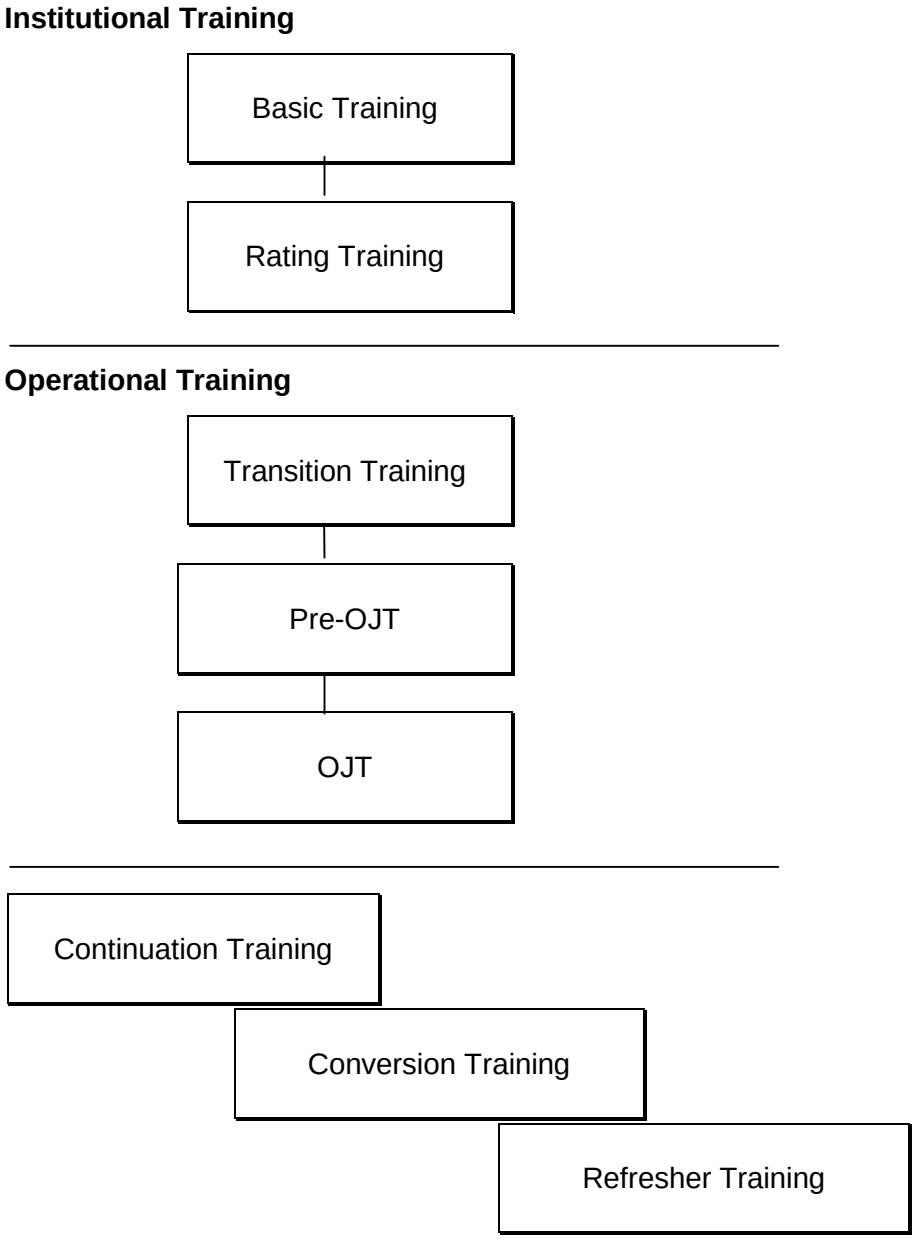


Figure 1: Phases of Training

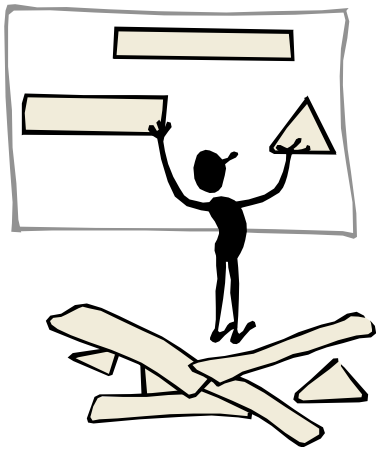
2.7 Assessment of Student Performance

During the last few years, as with other examination trends, there has been a move away from formal examinations toward continuous assessment. Even where examinations remain mandatory the students' performance during the course will account for a certain percentage of marks. As in operational training there will be an emphasis on a continuous assessment process with regular feedback given to the students.

2.8 A Modular Approach

The various training schemes for student air traffic controllers reflect the diversity of size and sophistication of the air traffic control units across Europe. At the institutional level basic courses will be reasonably standard but once specialisation starts training is tailored to the needs of the customers. A modular approach to training will allow for a high degree of flexibility which can serve future staffing needs as well as changing customer requirements.

Continuation, conversion and refresher training usually takes place on a needs basis and may be conducted locally at the air traffic control unit or at a training institute.



A modular approach to training …

2.9 Summary

The minimum content of basic air traffic control training is specified by ICAO. Student controllers progress through a number of stages in their training terminating in a checkout at an operational position. There is a trend to move away from formal examinations but a combination of examinations and long-term assessment may prove acceptable. A modular approach to training will allow for more flexibility in learning.

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3. THE CHANGING ROLE OF THE CONTROLLERS

3.1 Introduction

Whilst we may accept that air traffic control is a very conservative profession we must also acknowledge that it is technologically driven. Present ATM systems offer advanced tools that take over many of the controllers' routine tasks (e.g. strip marking) and for the future even some of their cognitive tasks. This trend may well change the function of the controllers and training will have to accommodate these needs.

3.2 What will be the Future Demand of Trainers and Trainees?

3.2.1 The Changing Roles and Tasks of the Air Traffic Controllers

The CAST project, funded by the Fourth Framework programme of the European Commission, has published material on the **C**onsequences of future **A**TM systems for air traffic controller **S**election and **T**raining (CAST, 1999). This study has identified four areas of change in future ATM systems:

- Cooperation and teamwork: It is suggested that decision-making will take place through a permanent dialogue between controllers and the system. There will be more cooperation between humans and computers in the air, as well as on the ground, with a greater emphasis placed on information sharing and the handling of air-ground relationships. Teamwork is likely to be more 'cognitive' in nature than the present 'vocal' arrangement.

- (Self)-awareness: The report suggests that controllers must become more aware of the system, its state, the role they themselves play and their workload. The controller will work with the system at a higher level – becoming a manager rather than an executor. The way the system provides information will need to be transparent, intuitive and logical and in a similar way to which the controllers process other information. Not only must controllers be aware of the state the system is in but they will also have to cope with (partial) system breakdowns.

- Flexibility: Most new systems will be introduced on an evolutionary basis requiring controllers to adapt to several levels of automation during transition. Concepts such as the Flexible Use of Airspace (FUA), Reduced Vertical Separation Minima (RVSM), traffic sequencing and tactical flow measures will be supported by enhanced computer tools and the automation of certain ATM processes.

- Automation: Flights will be managed on a 'gate to gate' scope. Enhanced computer tools will aid (and in some situations carry out) conflict detection, conflict resolution and planning. Information exchange will be by via data

link (air/ground) and by electronic exchange of information (ground/ ground).

New functions are likely to arise out of three broad areas of advancement – improved air-ground communications, enhanced aircraft-based systems and computerised strategic ATM aids.

Change will occur in four main areas:

- *cooperation and teamwork,*
- *(self)-awareness,*
- *flexibility,*
- *automation.*

As a result of these changes a number of controller tasks could disappear:

- Manipulating and marking strips;
- Planning future streams of aircraft;
- Detecting potential conflicts;
- Matching radar images to strips (maintaining identification);
- Coordinating actions with adjacent sector;
- Monitoring deviations from track;
- Handing aircraft over to next sector.

Many of the above tasks have already moved from a ‘manual’ to an ‘automated’ function and are being integrated into existing systems.

However, a number of controller tasks will remain:

- Determining how to resolve conflicts;
- Intervening to resolve conflicts;
- Complying with any special requests;
- Handling unexpected situations.

Team-oriented tasks and the need for overall system awareness by the controllers will play an even more important role in future systems.

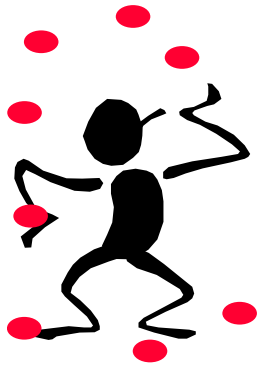
3.2.2 Changing Teaching Practices

Current teaching practices are considered to be out of touch with modern technology. Ideally, training techniques should be devised that will work with the trainees on the cognitive aspects of the new system including the demands likely to be encompassed by the next generation of systems, such as the concept of free flight.

Issues that have been identified and are likely to effect future working practices are those concerning automation and passive monitoring.

Major changes in such a complex system are always problematical because it is difficult to change ingrained attitudes and behaviours.

It is not easy to achieve the correct balance of academic classroom training, simulator training and OJT. Not only should this balance of training be carefully considered but the effects of a degraded system on the controllers' actions must also be taken into account.



Changes in system technology will undoubtedly mean new ways of thinking from the training managers' standpoint. Research has already warned of the 'Nintendo-syndrome' as some of today's student controllers demonstrate a game plan strategy instead of a real-time strategy.

As we have said, the introduction of new systems may degrade controllers' skills in some areas and therefore training, with and without systems, is needed.

Training is one of the most crucial issues when introducing new technology into a system. Training should therefore not only include the concept of 'how the system should be used', but also that of 'how the system works'.

CAST has identified four ways in which changes to future ATM systems will impact on the training of controllers:

- *Training content* – closely related to controller performance. What do the controllers need to know and what skills have they to be able to perform?
- *Training structure* – the overall structure of the training indicating what is learned in each phase.
- *Training methods* – described for each phase; for instance, individualised instruction, problem-based learning, part-task training, whole task training.
- *Training technologies* – that fit to the training task to be performed, to the training phase and to the training method applied.

Changes to future ATM systems will implicate the training of controllers in four main areas:
- training content,
- training structure,
- training methods,
- training technologies.

3.2.3 Impact on Training Content

Changes in cognitive skills (thinking) will occur in almost all tasks as the system becomes more complex due to the assistance of automated tools and the related change in work methods. For example:

- Extensive understanding and use of computer assisted tools;
- Being aware of the capabilities and limitations of the system;
- Increased scanning of displays and monitors;
- Using different communication procedures.

Changes in psychomotor skills (acting) will be mostly due to the interaction with the system. Much information will be presented by the system and will be handled in different ways. For example:

- Correctly perceiving (reading/hearing) the (pre-processed) information the system gives (perceptual acuity);

- Handling input devices and Human-Machine Interfaces (HMI);

- Being alert to system warnings.

There will be an increase in the need for affective skills (attitudes/reacting) in terms of task sharing and the need for flexibility of responsibility that will lead to more emphasis on some affective skills. For example:

- Workload detection and prevention of overload (self-awareness);
- Awareness of the role of the controllers;
- Gaining trust in the system.

'Gaining trust in the system'

Changes in social/interactive skills will evolve through changes in the way communication is undertaken and the need for increasing teamwork. For example:

- a shift to data link procedures and message windows;
- more teamwork through distributing decision-making;
- collaborative decision-making (with the system, aircraft and other controllers).

In general, the controllers will be required to maintain the same level of knowledge as today but types of knowledge may be used less often. There will be more generic knowledge use as new fields of knowledge (related to the system and its associated tools) become necessary.

In the concept of future ATM systems the job of the controllers will change with a corresponding impact on training. David Hopkin (1995) states “a change from tactical towards strategic control will place additional demands on training beyond those strictly required for the actual use of computer assistance”.

The 'mental picture' associated with the task of today’s controllers may differ substantially from that of the controllers working in future ATM systems. However, the question remains – how can the controllers maintain situation awareness?

The controllers must have an adequate mental model relating to different types of knowledge, perceptions of the ATM system, task demands and task performances in order to maintain situation awareness and understand the ATM situation.

Teamwork will continue to be an important component of air traffic control but with a different emphasis:

- Team training will have to include issues of automation and the system as part of the team to be controlled (Baldwin, 1991).
- Wickens, Mavor, Parasuraman & McGee (1998) recommend the continuation of formal training for controllers in teamwork, communications, distributed decision-making, conflict resolutions and coordinated response to unexpected events as a central aspect of controller training.
- Because most automation aids are more suitable for individuals than for team use (even communication can be silent) a different aspect of training for Team Resource Management (TRM) is needed.
- Future controllers will find it increasingly difficult to develop an understanding of the ‘professional norms, standards and ethos’ in air traffic control which are associated with the current dependency on humans in

the air traffic control system. As a result new tasks may be required to ensure that professional norms and standards are perpetuated.

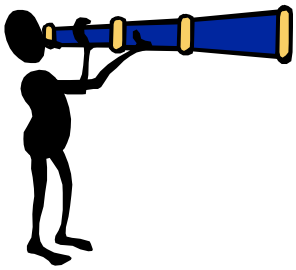
> *Training content will be affected by changes in the skills of thinking, acting, reacting and interacting. The 'mental picture' associated with today's control tasks may differ substantially from that of the controllers working in future ATM systems. Teamwork will remain important but with a different emphasis.*

3.2.4 Impact on the Training Structure

The first phase of controller training, which we will refer to as 'Institutional Training', usually consists of too much theory and too little practical work, despite the fact that the trainees have been selected for their ability to apply practical skills. With the use of low-cost personal computers many simple exercises, such as developing range and bearing skills, can be commenced very early in the course. Time for these exercises can be achieved by delaying theoretical work until later in the course. For example, much of the knowledge required for aerodynamics and meteorology is not needed when dealing with the initial practical skills. When these initial skills are mastered, the trainee is ready for more complicated exercises that are influenced by the real world of winds and visibility, aircraft performance characteristics, etc.

It is important that a thorough analysis of the task identifies the required knowledge and skills to be learnt. It is uneconomic and demotivating for students to learn material that is not relevant to the task.

On-the-Job-Training (OJT) techniques will change substantially with the advent of automation and the use of expert systems or artificial intelligence. It will still be possible to give knowledge to trainees through remote learning techniques. However, there is a drawback of producing controllers who are capable of solving specific problems rather than having mastered the groundwork of general principles and practice (Baldwin, 1991).



'…give knowledge through remote learning techniques.'

A different set of guidelines will be needed for *Ab Initio* training and for conversion training. In *Ab Initio* training the student controllers will have little experience in traditional (radar) methods of controlling air traffic but will learn to work with the future system. Qualified controllers, however, will have to adapt to several levels of automated system and operating procedures because systems will not be introduced in one phase, but gradually.

Conversion training will have to precede any implementation of the system and will have to take into account the experience of traditionally qualified controllers who have a lot of knowledge of existing procedures but who will have to adapt to the new environment. In this situation motivational as well as affective aspects of learning will play an important role.

> *The training structure will require review in the three phases of institutional, on-the-job and conversion training as new systems will impact differently on the controller population.*

3.2.5 Training Methods and Tools

Individualised Instruction

In recent years the philosophy throughout air traffic control training programmes has become 'train for success' (Wickens, Mavor & McGee, 1997). Instead of imposing several pass/fail levels in the training process, the idea should be to provide a supportive learning environment. A new training philosophy should be ”Design enough treatments to allow everyone to succeed using their own preferred modalities of learning” (Smith, 1991). This could lead to the term 'individualised instruction' becoming a common denominator in all curriculum design and content development of air traffic control training.

Present air traffic control training programmes will need to move from instructional-centred techniques to individual learning capability within the framework of group development, thus learning the skills and knowledge at a pace suitable for each individual but still within the scope of the teams development (Baldwin, 1991).

Changing demographics in the workforce, increasing shortages of high-potential, low-risk candidates and intense competition for talented new candidates are examples of the external changes that must be accommodated by adaptive training systems (Smith, 1991).

Computer-based Training

Free navigation through Computer-Based Training (CBT) and practice of interactions as often as wanted is necessary in learning such a complex system (Roessingh & van Blanken, 1998). Using CBT will also require a

performance monitoring system with a good test and feedback structure in the first stages of skill acquisition.

Simulator Training

The real-time and dynamic nature of air traffic control suggests the importance of simulator training as early as possible in instruction (Redding, Cannon & Seamster, 1992).

Trainees' performance can be replayed as a means of providing immediate, detailed and corrective feedback (Rodgers & Duke, 1994).

Instructions should also be delivered so that small chunks of related knowledge and skills are taught, followed by simulation-based instruction and practice (Redding, Cannon & Seamster, 1992).

Pause and replay possibilities on the air traffic control simulator are very desirable during training, which allows time and opportunity for discussion, reflection and problem-solving (Roessingh & van Blanken, 1998).

Problem/Scenario-based Learning

The traditional approach of providing knowledge application only after completion of all classroom instruction makes it difficult for students to integrate the knowledge with real-time controlling skills (Redding, Cannon & Seamster, 1992). Using a problem-based approach to training actual problems can provide the context for assimilating basic domain knowledge.

During the early stages of instruction, it is important that students practice thinking about aircraft in terms of events. Later, they will learn the relevance of various event types (Redding, Cannon & Seamster, 1992).

Laboratory exercises should consist of two parts: scenarios exercising both typical and non-typical functionality and sessions on the operational floor, interacting with real world activities as they evolve (Bergeron & Heinrichs, 1993).

Individualised instruction, problem-based learning, CBT and simulation are all methods of training to be more effectively applied in training for future ATM systems.

3.2.6 Training Technologies

Computer-based Training

Implementing HMIs into a CBT package on a PC costs much in effort but gives more possibilities to implement educational strategies such as feedback and help than training HMI on a workstation (Roessingh & van Blanken, 1998).

Computer-based learning techniques will prove valuable as the trainees can explore their own capabilities and skills and decide on task levels to be undertaken and strategies for dealing with the tasks and work scheduling (Baldwin, 1991).

Simulators

Extensive use of either stand-alone or integrated facilities to conduct the transition training and pre-OJT phase of operational training will bring the trainees to a much higher level of performance than has been experienced in the past. Introducing low-fidelity stand-alone PC-based simulators in transition training and high-fidelity, site-specific and integrated simulators in the pre-OJT training will significantly reduce the occupancy time in live traffic situations and allow greater flexibility (EATCHIP, 1995).

There is the added benefit that a higher level of performance by the trainees can be achieved because these systems give possibilities to implement instructional strategies in the system, adapt traffic scenarios to the trainees' needs and pause and replay scenarios whenever needed (EATCHIP, 1995).

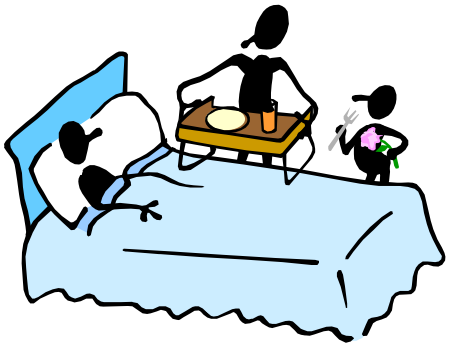
More sophisticated media mentioned for future controller training are intelligent tutoring systems, embedded training systems and virtual reality. At this time little is known concerning the application of these technologies in training because research in these areas is in its infancy. However, within the next twenty years it is possible that these media may be used in controller training and, therefore, potential applications of these media will be mentioned below.

Intelligent Tutoring Systems

An ideal instructional system for learning cognitive skills (similar to air traffic control skills) would involve computer-based intelligent tutors that could prompt students about task triggers, that is, when and how to do a task (Redding, Cannon & Seamster, 1992). It would also assist the students in keeping track of unfinished or next priority tasks when more critical tasks capture attention. Student proficiency could be assessed with prompts that fade out as the student gains proficiency.

Embedded Training Systems

Embedded training appears to be an extremely useful approach to helping controllers maintain those skills, which are not applied during normal operation of the automated system. Such skills would be called on when an automated system degrades or otherwise forces the controllers to function at a lower level of automation (Wickens, Mavor, Parasuraman & McGee, 1998).



'Embedded training systems?'

Virtual Environment Technology

Virtual reality technology will open new opportunities for knowledge acquisition and skills training. How, or in what manner, it could be applied to air traffic control training is not yet clear.

> *Further development of CBT and air traffic control simulators together with the introduction of intelligent tutoring systems, embedded training systems and virtual environment technology offer exciting possibilities for future training tools.*

3.2.7 Summary

The introduction of future ATM systems will impact on air traffic control training. New tasks will challenge the controllers to acquire new skills. The existing system of training air traffic controllers needs to be critically appraised and suitable teaching methodologies adopted to best serve the development and maintenance of these new skills.

Four areas of change which affect the controllers (cooperation and teamwork, self-awareness, flexibility and automation) have been identified in future ATM systems. It is expected that entirely new functions will arise out of three broad areas of advancement: improved air-ground communication, enhanced aircraft-based systems and computerised strategic ATM aids.

These changes will have implications for controller training in training content, the structure of training, training methods and in training technology.

The ‘mental picture’ associated with today’s control tasks may differ substantially from that of the controllers working on future ATM systems. Teamwork will remain important but with a different emphasis as tasks become more ‘cognitive’ and individual.

Training will have to take account of how the new systems will impact differently on the controller population. Training methods such as individualised instruction and problem-based learning should be given consideration.

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4. MOTIVATION - WHY PEOPLE LEARN

This chapter aims to explain theories about motivation, with emphasis on more recent findings, in order to find some answers to the question 'why do people learn?'

4.1 A Historical Perspective - Instincts, Needs and Drives

These historical views of human motivation may help us to understand human behaviour in general.

4.1.1 Imprinted Behaviour

We usually explain animal behaviour by instincts: innate, complex, species-specific and relatively unmodified behaviour patterns. It would be difficult to find a human behaviour that can be described as such. More useful are the concepts of imprinting at a critical period in the animal's life, like the 'following' behaviour of young ducks (see Figure 2).

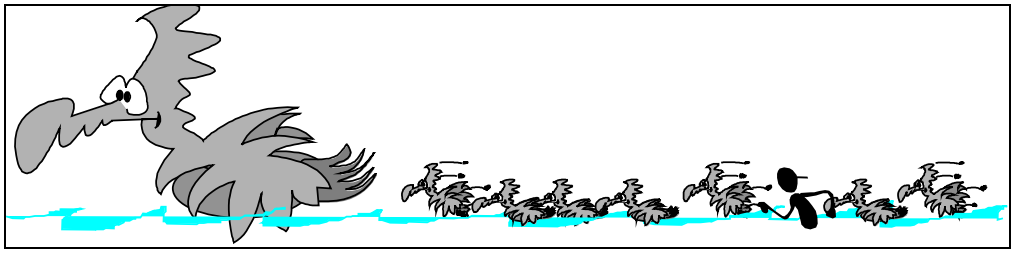

Figure 2: Imprinted behaviour

Imprinting is a form of learning and has been linked to some features of infant development. Although the behaviour of children is not imprinted in the same sense as animal behaviour, there might be particularly sensitive periods for certain developments during childhood. An example is the establishment of very strong attachment bonds between child and parents during the first six months of the child's life.

4.1.2 Pain and Pleasure

Another theory says that motivation comes from our attempts to avoid pain and to obtain pleasure (psychological hedonism). This seems a reasonable assumption except that the theory does not define what is pleasurable or what is painful. And it is essential to know these conditions if we want to apply this principle in the prediction and control of our behaviour.

4.1.3 Needs and Drives

The needs/drives theory offers definitions for pain and pleasure. Needs are states of deficiency or lack within an organism. Drives are the energies or tendencies to react that are aroused by needs. The link between the

needs/drives theory and psychological hedonism is the assumption that a state of need is pain and that satisfying needs is pleasant. Therefore, a list of needs is helpful in understanding the conditions for pleasure and pain. We can divide needs into two categories: physiological and psychological.

With regard to learning it is important to note that a learner being in a state of unsatisfied physiological need (like hunger or thirst) will concentrate on satisfying this need and not so much on the lesson.

> *Human behaviour is not only ascribed to instinct. The historic perspective describes pain and pleasure as motivators but this depends on the individuals' point of view or preference. However, we can make the assumption that a state of need is a pain and that satisfying needs is pleasant. These needs can be either physiological or psychological. The 'carrot and stick' approach seems today to be a bit limited. Human motivation is more complex.*

4.2 Some More Recent Developments

4.2.1 Arousal

Arousal is a concept to describe the level of activation of a person. It is a term used both for psychological and physiological states. In the psychological sense it is the individuals' degree of wakefulness, ranging from sleep to normal alertness and at a higher level to a state of panic or shock. Physiologically, it refers to the functioning of the sympathetic nervous system like respiration, heart beat or brain wave activity. The main source for arousal is stimulation. The degree of arousal is influenced by stimuli like meaningfulness, suddenness, intensity, novelty and complexity.

4.2.2 Arousal and Motivation

There is a correlation between arousal and motivation. Motivation increases with increasing arousal until it reaches an optimal level. Further increases in arousal will result in decreasing motivation and a resultant decreasing effectiveness of behaviour (see Figure 3 for a simplified illustration). The relationship between behavioural performance and arousal is referred to as the Yerkes-Dodson law. This law has two underlying assumptions. The first assumption is that there is a level of arousal at which individual performance will be optimal for any given activity. Certain activities can best be performed under conditions of relatively high arousal, whereas others are best performed under conditions of lower arousal (Lefrancois, 1997). The second assumption is that individuals behave in such a way as to maintain the level of arousal that is most nearly optimal for ongoing behaviour. In the case of too high an arousal we take steps to return to a lower level, and in the case of too low an

arousal we take action to achieve a higher level. When we are bored our arousal level is probably too low. Important for learning is the fact that low arousal is accompanied by low attentiveness and thus by less effective learning. Potentially interesting lessons can easily be destroyed by boring teachers and the students will achieve nothing. However, the same lessons presented in a lively way, or as an interactive experience, often lead to evaluations like 'inspiring', 'arousing', 'stimulating', 'challenging', 'exciting', etc., all ways of expressing 'motivating'.

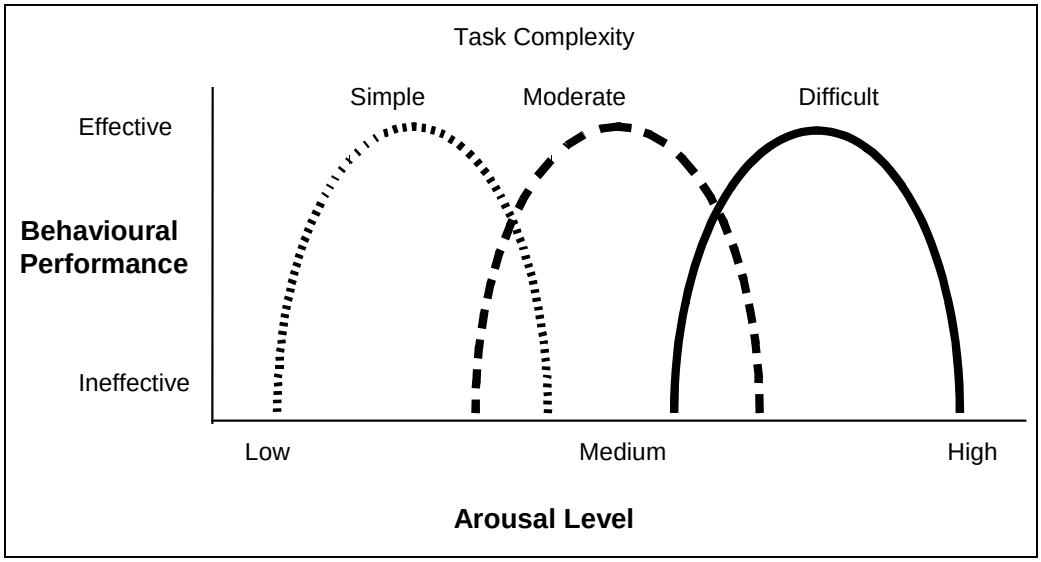

Figure 3: Behavioural performance and arousal

4.2.3 Too Much Is Too Much

On the other hand, too high an arousal can be a disadvantage. Anxiety is a manifestation of increasing arousal. A good example is the anxiety experienced by students doing tests. Students suffering from test anxiety achieve poorer test performance, have a lower self-esteem and do not profit as much from instruction. There are techniques available to reduce test anxiety. Some techniques aim to change the students' attitudes about their competence and teach them to concentrate on the task rather than on feelings of worry. Other techniques focus on changes in instructional and evaluation methods, like application of time management strategies in learning.

> There is a correlation between motivation and arousal. Motivation increases with increasing arousal until it reaches an optimal level. But, too low or too high a state of arousal is detrimental to performance.

4.3 Behaviour and Its Consequences

We can try to understand behaviour by looking for the conditions that cause it. Our actions are very often controlled and regulated by the consequences following a particular behaviour. Because of these consequences, the frequency of certain behaviour can be increased or decreased. Some stimuli (or situations) have an increasing effect on the probability of our behaviour. They are called reinforcers. Reinforcers, like praise or reward, are components of extrinsic motivation, i.e. motivation governed from outside of ourselves.

External reinforcement is used to a great extent at school. Every time teachers show approval or disapproval to the behaviour of students, it is an attempt to influence the students' behaviour. Consider praise or punishment, a smile or a frown. If teachers use these reinforcers in a systematic way they can have a clear impact on the students' behaviour.

4.4 Praise

A strong and very common tool for increasing a desirable behaviour is praise. The efficiency of praise, however, depends on its perception by the student,. Unfortunately, praise is often given carelessly with a resultant negative perception by the students. It is important to pay attention to some rules, especially for adult learners. Here are just a few guidelines for effective praise.

Guidelines for Effective Praise

EFFECTIVE PRAISE	INEFFECTIVE PRAISE
Is delivered systematically	Is delivered randomly or unsystematically
Specifies the particulars of the accomplishment	Is restricted to global positive reactions
Rewards attainment of specified performance criteria (which can, however, include effort criteria)	Rewards mere participation without consideration of performance processes or outcomes
Provides information to students about their competence or the value of their accomplishments	Provides no information at all or gives students information about their status
Attributes success to effort and ability, implying that similar successes can be expected in the future	Attributes success to ability alone or to external factors such as luck or ease of the task

Reinforcers are stimuli that have an increasing effect on our behaviour. Some of them, like praise and reward, are components of extrinsic motivation. The efficiency of praise depends on its perception by the recipient.

4.5 Humanistic View

The humanistic view is concerned with internal or intrinsic motives like autonomy, dignity and the worth of individuals. A well-known example for the humanistic view is Maslow's theory of human needs.

4.5.1 Maslow's Hierarchy of Needs

Maslow says that we have two general need systems: basic needs and meta needs. They are hierarchical in that we take care of higher level needs only after lower level needs are satisfied (see Figure 4). The basic needs include physiological needs, safety needs and love and belongingness needs. The basic needs are also called deficiency needs because they lead to actions when there is a deficiency with regard to a need. The meta needs are called growth needs. They do not result from a deficiency but from the natural human tendency towards growth. Meta needs include cognitive and aesthetic urges like acquisition of knowledge, symmetry, goodness, beauty, justice and truth. The highest need is the tendency towards self-actualisation - the fulfilment of self. Self-actualisation is more an ongoing process of growth than a state. Learning, in this view, fulfils the natural tendency towards growth.

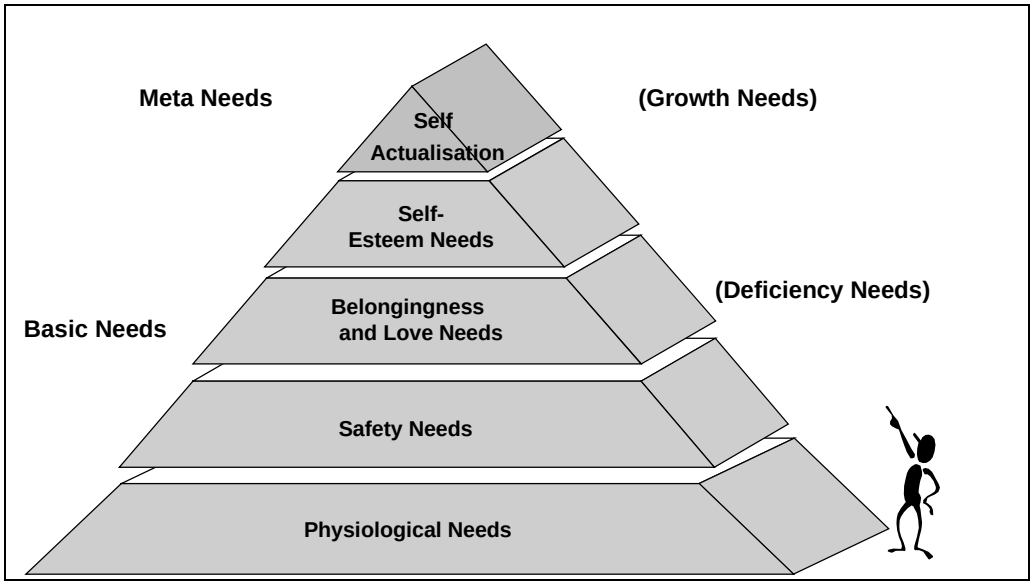

Figure 4: Maslow's hierarchy of needs

4.5.2 Competence, Motivation and Learning

A very important intrinsic need is the need to feel competent. Manifestation of this need is in the feeling of confidence and worth in a situation where we performed well and were successful. Children are born with only a few innate competencies and growing up means learning thousands of new competencies. The struggle for competence - for children and adults - is rewarded by feelings of pride and success as the result of mastering a skill.

> *Motivation is driven by needs. Basic needs (which include physiological, safety, love and self-esteem needs) lead to actions to overcome the deficiency with regard to a need. Meta needs are a process not a state and motivate behaviours resulting from the natural human tendency toward growth. Competence is an important intrinsic need rewarded by feelings of success at mastering a skill.*

4.6 Cognitive Views

Cognitive approaches emphasise the human need to know and understand. We do not only react to stimuli from our environment or from internal drives, nor do we only follow a simple pain/pleasure principle. We are able to delay gratification and that is a very important ability for the achievement of long term goals like completing education. Accepting delay of gratification requires cognitive functions like thinking and anticipation. What is relevant for motivation are so-called self-referent thoughts. These are thoughts that have to do with ourselves and with our own mental processes.

4.6.1 Self-efficacy

Self-efficacy has to do with our estimate of our own personal effectiveness. It consists of two components. The first component has to do with the skills that are needed to achieve success in a certain task and the second component is the personal estimation of competence. This internal judgement is extremely important for the effort someone makes in achieving a (learning) goal. This judgement, by the way, can be influenced to a great extent by others (e.g. teachers).

4.6.2 Influences on self-efficacy judgements

Bandura (1986) gives four main sources for our estimation of self-efficacy:

Enactive influences come from the results of our actions. If we are successful in completing a certain task we will develop a highly positive judgement of our abilities. If we constantly fail, then we will conclude that we are not very competent in this area.

Vicarious influences take effect when we observe the performance of others. We compare our own achievement with that of others and use this as a basis for the evaluation of our own competence.

We speak of *persuasive influence*s when somebody tries to convince us of our abilities. Persuasion includes a positive judgement of our skills and is therefore important for people who lack confidence.

Emotive influences are linked with arousal or alertness. Immediate emotional reactions can affect self-judgement in different ways. Faced with a large audience speakers may be overcome by fear and decide they are incapable of continuing or, in contrast, great fear may lead walkers to judge that they are capable of outrunning a bull.

4.6.3 Implications of Self-efficacy

Self-efficacy is extremely important for what we do and what we do not do. Our estimation of our abilities influence how we feel, how we think, how we motivate ourselves and how we behave. They guide as well the amount of effort we spend on a task. If we expect to be able to complete the task, we will persist in it - even when we are faced with difficulties.

'If we are successful we will develop a highly positive judgement of our abilities.'

Self-efficacy is also related to our goals. When we believe in our skills we set ourselves higher goals (like learning goals). As a consequence we are more successful in achieving these goals. As goals are a criteria for success (when we achieve them) or failure (when we do not succeed), then they can have a strong impact on our emotions and on our self-esteem.

But the nature of this impact also depends on how we attribute our success or failure. This will be described in Chapter 4.7.

Our estimation of self-efficacy depends on the results of our behaviour (enactive influence), comparison with others (vicarious influence), persuasion by others (persuasive influence), and the intensity of arousal (emotive influence). Our self-efficacy is important for what we do or do not do. However, we do need the skills to achieve success in a certain task and to have a personal estimation of competence.

4.7 Attribution Theories

Attribution theories seek the source of our behaviour (and our motivation) by looking at the way we attribute the outcome of our behaviour.

Individuals attribute the results of their behaviour to different causes. Whether we attribute success to our ability or simply to luck depends on three factors: the locus (place) of control, personal responsibility and stability. These factors will help us to understand why some students are highly motivated toward achieving their goals whereas others give up easily.

4.7.1 Internal or External

We differentiate an internal and an external locus of control. If people have an internal orientation they attribute their success or failure to factors within their own persons like theirs ability or effort. Having an external orientation means that they attribute their achievement to luck or task difficulty - to factors outside their person.

4.7.2 In Control or Just Lucky?

We can attribute the results of our behaviour to causes over which we have control. We are then of course personally responsible for the result. An example is when we attribute a poor grade to the effort (or lack of) we made when preparing for a test. But people can also attribute their achievement to uncontrollable causes, which they are not able to influence, and for which they do not have to bear personal responsibility. Attributing a good grade to luck would be an example.

4.7.3 Stable or Unstable

The third factor defining our attributions is stability. The causes we assume for outcomes (see Table 1) can be stable and unchangeable like the complexity of a subject or they can be highly unstable and changeable like the effort we put into the preparation for exams. In the first case we may not expect to do any better the next time because the subject remains complex. However, in the second case we can hope to get a better result.

Table 1: Attribution of causes of successes and failures

ATTRIBUTION	**Internal**	**External**
Unstable	Effort (controllable)	Luck (uncontrollable)
Stable	Ability (uncontrollable)	Difficulty (controllable)

The following examples will help to illustrate this principle of attribution:

Effort – 'I failed the exam because I didn't study enough'
'I passed the exam because I worked very hard'

Luck – 'I failed the exam because Mr. Jones was my examiner'
'I passed the exam because I was lucky with the questions'

Ability – 'I phailed the exam becos I'm no good at speling'
'I passed the exam because I'm very good at mathematics'

Difficulty - 'I failed the exam because the questions were too complex'
'I passed the exam because it was so easy'

The three dimensions of causes (locus of control, personal responsibility and stability) show us the four most important attributions students make for the outcome of their learning activities. Students can attribute their achievement to effort, luck, ability or the difficulty of the task. Each of these attributions has a different impact on the students' motivation to learn. Personal perception as to the reason for a result has impact on the motivation. For example, an unstable, internal, controllable attribution (like effort) will sustain high motivation.

4.8 Summary

Historical views of human motivation may help us to understand human behaviour in general but we need to look at more recent studies to have a better appreciation of what motivates people to learn. Understanding and sustaining the intrinsic motivators of learners will help us to provide more effective training. In current training practice the teachers try to motivate the learners. Recent theories show that motivation comes from the learners. The teachers only facilitate the conditions to help self-motivation.

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5. HOW PEOPLE LEARN

In this chapter we try to give an overview of some traditional (but still relevant) and some more recent theories of human learning. As there are so many theories and approaches to learning we are not able to review all of them. We have therefore selected the more familiar proven theories and approaches which seem to have most interest and application in the context of air traffic control training.

5.1 What is Learning?

Not every behaviour we demonstrate is something we learned. When you withdraw your hand after having touched a hot stove this is a reflex behaviour. But, if you avoid touching it because you know already how it feels to burn your fingers, you show a learned behaviour. In more scientific terms learning can be seen as a persistent change of behaviour resulting from experience (and not from fatigue, maturation, drugs, injury or disease).

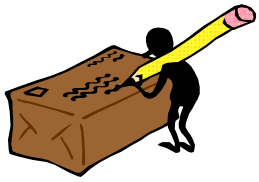
5.2 Basic Principles of Learning

Already at the very beginning of this century researchers developed theories about the process of learning. This approach on human learning was strictly focused on observable behaviour. For that reason this approach is called 'behaviourism'. Two main theories of behaviourism are still important today: the first one is 'classical conditioning', the second one is 'operant conditioning'.

5.2.1 Classical Conditioning

Early behaviourists like Pavlov or Watson were looking for the basic elements and laws of learning. The mechanisms they found can explain human as well as animal behaviour. These mechanisms produce a learned reaction (or a so-called conditioned reaction) in the following way: a neutral and a meaningful stimulus are presented repeatedly together until the neutral stimulus alone causes the intended reaction. The most famous example for this kind of learning is the experiment Pavlov made with dogs. Pavlov observed that the dogs already started to salivate before they got their food. He combined a tone with the feeding of the dogs and after a certain while the tone alone (without any food) produced the reaction of salivation.

Classical conditioning is almost totally an unconscious process. Nevertheless, it can be used consciously to obtain a desired reaction. As a learner you can conduct your studies always at the same place (the same table, in the same room - as school children usually do) and at a certain time. If you do this regularly, it will be much easier for you to get into the right 'mood' for learning in this specific surrounding.



'…at the same table, in the same room.'

5.2.2 Operant Conditioning

In a further step behaviourism described a principle of learning that is governed by the consequences of certain behaviour. Preferably we produce a behaviour we have been successful with in the past.

Operant conditioning assumes that a behaviour with pleasant consequences will show up more often. These pleasant consequences are called 'reinforcers'. On the other hand, it is less likely that we repeat a behaviour that was followed by negative reactions from our environment. This is the case for all kind of punishment.

The principle of operant conditioning is very important in our present school system. High or low grades are typical examples for reinforcement by reward (high grade) and punishment (low grade). Smart teachers will always try to get their classes where they want them by reinforcing the desired behaviour (e.g. by praise) instead of punishing disturbing behaviour. Operant conditioning can be a very powerful tool in your own hands. Assume you have to do an unpleasant task like learning a chapter in a textbook you are not interested in. You can promise to yourself that after every section you managed to learn you will reward yourself with a cup of coffee and after finishing the whole chapter you will go out for a beer. But of course it is not allowed to cheat!

5.3 Social Learning

Up to now we have been talking about the behaviour that individuals already knew how to produce. Learning seems to work by conditioning existing behaviour. But how can we acquire a behaviour that was not known to us before?

For example, one way of learning is simply to look at others and observe what they are doing. This so-called social learning is something very natural. All parents are role models for their children in all circumstances of life.

In the world of air traffic control On-the-Job-Training (OJT) is a good example for social learning. But before trainees are able to copy a behaviour they must fulfil the four criteria of social learning: the trainees must attend to the model, remember what the model did, see the usefulness of the model's behaviour and be able to duplicate the behaviour (after some practice). This process works quite well for behaviour which is neither too complex nor too difficult to acquire and which can easily be observed. However, what about more complex patterns of behaviour and behaviour which cannot be observed at all because many mental processes are required?

> *Behaviourism focuses on observable behaviour and defines three ways of learning: classical conditioning, operant conditioning and social learning.*

Behaviourism insisted on concentrating on observable behaviour. This limitation led to the development of a new approach. The cognitive view takes into account all the mental processes contributing to learning.

5.4 Cognitivism: Do we Think when we Learn?

Cognitive psychology makes the attempt to describe and explain human mental functions and activities. As these mental aspects cannot be observed cognitive theories quite often use metaphors to describe their findings. The most common metaphor is to compare the human brain to a computer.

When we talk about how people learn we have to take into account how our memory is working. For that reason we will first describe a model of human memory.

Our memory consists of three interacting parts: the sensory memory, the short-term memory and the long-term memory. This can be expressed in the model shown in Figure 5.

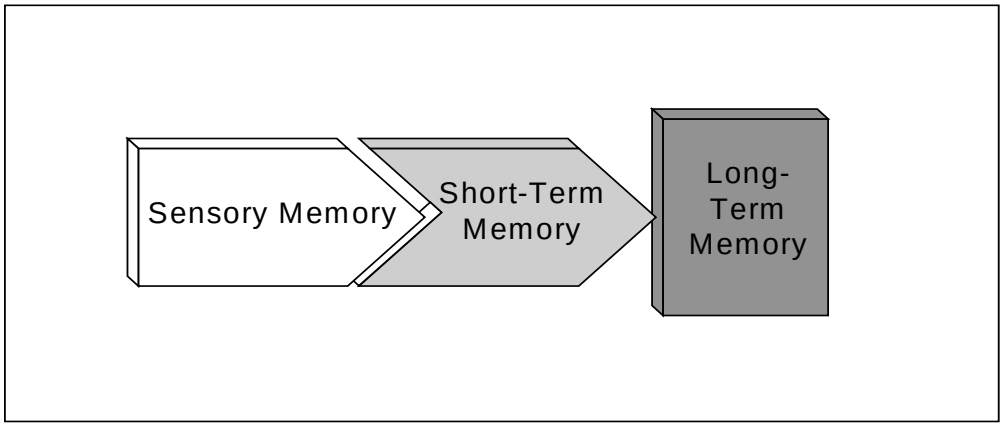


Figure 5: A simplified model of human memory

5.4.1 Sensory Memory

The sensory memory keeps stimuli from our environment only for a very short time – a matter of milliseconds. This time is sufficient for our brain to make a first check to see if some input is meaningful and important enough to be kept in memory. All information considered as not important diminishes immediately after this first rough check. The sensory memory is guiding our attention in a way that we become aware of the information considered as meaningful and important. An example is the 'cocktail party phenomenon' (Cherry, 1953) (see Figure 6). Even if you are not listening to a conversation going on behind your back, you will pick it up immediately if somebody mentions your name or talks about you or about something that passionately interests you.

Figure 6: The 'cocktail party phenomenon'

In the world of air traffic control we have a similar phenomenon: controllers immediately recognise calling pilots even if they are involved in a discussion with the coordinating controller.

From the sensory memory important and meaningful information will be forwarded to the short-term memory.

5.4.2 Short-term Memory

Short-term memory lasts for seconds or a very few minutes at most. It contains information that will get lost if the individual stops rehearsing it. Imagine you have to dial a telephone number you are not familiar with. You repeat it until it is dialled. Afterwards, you find that you have forgotten it almost immediately.

Short-term memory is an ongoing process of availability of information. In other words it is what is conscious at any given time. Short-term memory is a kind of 'scratch pad' for thinking and is often called the working memory.

Furthermore, it has a limited capacity. Only seven plus/minus two items can be stored at a given time. But these items do not have to be single units like a digit or a letter. They can be 'chunks' of information like a word or very short phrase. These chunks are far more economical and usually more meaningful than unrelated information.

In brief, the purpose of the short-term memory is to keep information for only as long as it is useful and then to discard it.

5.4.3 Long-term Memory

Long-term memory is what people usually mean when talking about memory. It stores all kinds of information for a long time and is virtually unlimited in its capacity. Long-term memory is highly stable (unlike short-term memory) and things can be remembered for a long time.

Our long-term memory consists of two different components: the declarative memory and the procedural memory. The declarative memory has two sub-components: the semantic memory and episodic memory. We can distinguish them according to the kind of information or knowledge they store.

The procedural memory contains unconscious and non-verbalisable effects of learning like motor skills. For example, you may know how to ride a bicycle even if it is very difficult to explain how to do it without demonstrating it.

In the declarative memory we can find the semantic memory containing all our abstract knowledge that underlies facts, strategies, language, principles, etc., and the episodic memory that contains our personal, autobiographical knowledge.

Table 2 shows a comparison of the three different levels of memory.

Table 2 : The three levels of memory

Characteristic	Sensory memory	Short-term memory	Long-term memory
Duration	Less than one second	Less than twenty seconds	Indefinite
Stability	Fleeting	Easily disrupted	Not easily disrupted
Capacity	Limited	Limited (7+/- 2 items)	Unlimited
General Characteristics	Momentary, unconscious impression	Working memory, immediate consciousness; maintained by rehearsal	Knowledge base; the result of encoding

5.5 Levels of Learning and Performance

In the mid-eighties, Rasmussen discussed three levels of human performance. These levels of performance are closely linked to the stages of learning that every individual experiences when they transfer from conscious to unconscious control of skilled action. Rasmussen carried out a number of studies in industry and concluded that there were different levels of functioning of a human (Rasmussen, 1983). These levels were classed according to the control exercised over the action along with the situation, and are summarised in Table 3. In terms of learning a person may be at any of the three levels of control and performance, and in any of the three situations. Typically these levels of control are associated with the type of the memory systems available.

Table 3: Levels of performance

SITUATION	CONTROL		
	Mainly Conscious	Conscious and Automatic	Mainly Automatic
Routine Expected			***Skill-based Performance***
Familiar or Trained-for Problems		***Rule-based Performance***	
Novel, Difficult or Dangerous Problems	***Knowledge based Performance***		

At the skill-based level of learning an individual will rely heavily on long-term memory, that is, an already established set of skills, which can be automatically accessed. At the rule-based level, an individual will use those rules and procedures that match the task. For this reason the use of both long and short-term memory is accessed. Once an individual has to search and extract knowledge and information to respond to a more novel situation, the use of the working memory is of more importance.

5.5.1 Skill-based Performance and Learning

At the skill-based level it can be seen that the types of activity are usually routine and automated. This type of performance tends to encourage problems in learning which are associated with attentional or memory failures. These can be demonstrated by omitting information or forgetting what to write.

When learning skills at this level an individual may suffer memory slips and lapses in performance. These are problems faced by all humans who do many of their actions in an automated way. Normally the consequences of these problems are trivial, such as trying to open your front door with your car keys. However, the same types of error can be more serious depending on the circumstances and environment. Turning the radio on instead of the compact disk is just inconvenient, but hitting the wrong switch, such as the crash alarm instead of the runway lights, could be considered more serious.

5.5.2 Rule-based Performance and Learning

At the rule-based level of activity, an individual uses certain types of response to known and often rehearsed scenarios. For instance, in the training environment the Manual of Air Traffic Services (MATS) would be classed as

material in rule-based learning and in air traffic control the use of separation procedures and weather limits would be classed in a similar way.

Rule-based mistakes in performance involve the application of already known but inappropriate solutions to problems that have been encountered many times before or which have been highly trained. Rule-based mistakes can be divided into two types: the misapplication of good rules and the application of bad rules. This level of learning is extremely important in both *Ab Initio* and in transition training. At *Ab Initio* level, bad habits developed early in learning are very difficult to reverse later in training. By the same token those skills which have been developed in one system may have to be adopted quite radically in another more automated system, i.e. the change of information recorded and used on a paper versus an electronic flight progress strip. This has serious consequences when highly automated systems replace more traditional architecture. Often errors are made because the first characteristics of early learning will be reverted to when an individual is under stress and time pressure.

5.5.3 Knowledge-based Performance and Learning

Knowledge-based performance is the result of skill, ability, observation, training and experience. These variables will enable us to tackle novel, difficult or even dangerous situations with adequate reliability and in most cases the likelihood of a successful outcome.

In most cases we are able to accomplish these successes through trial and error, although in air traffic control most controllers will also have the benefit of long hours of strict training and supervision. Controllers should actively train for some of the more unusual occurrences to be encountered, such as emergency calls, lost pilots or an incident in their airspace. In this way they may be able to handle such occurrences in a more systematic way, using problem solving techniques already known and familiar to them. Much of the success attributed to the recovery from the catastrophic accident at Sioux City in 1989 was due to thorough rehearsal of all the emergency teams and the contingency plans which were created by all the major groups at and around the airport, including the air traffic controllers. In many cases the response to a knowledge-based situation can be managed at a rule-based level depending on the circumstances.

> *It is important to recognise that individuals learn in a rather orderly way, the speed of which can however vary. The transfer from more automated to problem-solving performance is the result of the transition from unconscious to conscious behaviour. This transition demands the different use of the memory system and as such a change from a dependence on long-term memory to that of active working memory. This transition has an important bearing on the attentional demand of the tasks to be learned and should therefore be considered carefully both at the early and the transitional stages of air traffic training.*

5.6 How We Memorise

There are three main strategies to support the transfer of information from short-term to long-term memory: rehearsal, organisation and elaboration. These are also the main cognitive processes of learning.

Rehearsal is the process of repeating something again and again (like 'His number is 4360611, 4360611, 4360611, etc.'). Rehearsal is the basic means for maintaining information in short-term memory. It can also be used for moving material to the long-term memory. Rehearsal is a very simple strategy. Even young children use it spontaneously if they want to remember something.

Organisation is the arrangement of information according to a system. It can, for example, be chunking (placing what is to be learnt into related groups), finding a hierarchical order of material, or organising textual material with headings and subheadings. This organisation strategy is used frequently as it seems that humans have a natural tendency to look for relationships, to categorise and attain concepts.

Elaboration (meaning to extend or add to) involves relating new material to material that has already been learned. It can also mean to link what is to be learned with mental images. For example, it is much easier to remember the sentence 'The fat man read the sign' if it has been elaborated to 'The fat man read the sign warning of thin ice'.

Apart from these three strategies there exist other strategies - the so-called mnemonic devices. They are based on the main strategies but emphasise certain ways to organise or to elaborate. Often mnemonic devices highlight the importance of retrieval cues. Some of them suggest the use of visual imagery, some advise to use rhymes and little sayings.

Memory consists of three interacting parts: the sensory memory, the short-term memory and the long-term memory. Each has a specific function and a defined duration. Sensory memory makes us aware of meaningful information. Short-term or working memory is our 'scratch pad' for thinking. Long-term memory is highly stable and stores information for a long time. Strategies for remembering include rehearsal, organisation and elaboration.

5.7 The Learners are Humans

After having read the section about cognitive approaches and its computer metaphor, it could be that we have lost sight of the human involved in these

cognitive processes. To focus on the human being is the concern of the humanistic approach to learning. Humanistic schools concentrate on the uniqueness of people, on the self and individual development. We can find four cornerstones in humanistic education: affect, self-concept, communication and personal values (see Figure 7).

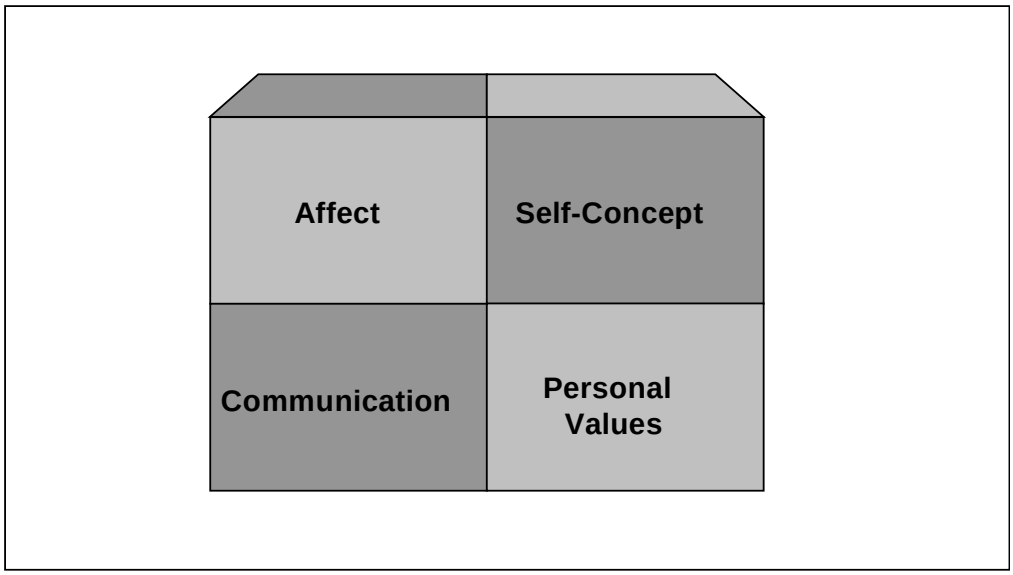


Figure 7: The four cornerstones of humanistic education

Humanistic schools consider thinking and feeling (affect) more important, or at least as important, as the acquisition of knowledge. Second, they place emphasis on the development of individual identity and a positive self-concept. The students should be reached as individuals, touched or motivated as human beings and still taught in a systematic fashion. The third cornerstone is communication. The attitude of teachers towards their students is an important aspect. Teachers should be able to build up a good teachers-learners relationship and to solve conflicts in a constructive way. The final emphasis is on the development of personal values. Students are encouraged to know and express themselves and to develop a feeling of self-identity.

Humanistic approaches to learning focus on the uniqueness of people, on the self and on individual development. The four cornerstones of humanistic education are affect, self-concept, communication and personal values.

5.8 Classroom Application

In addition to these more attitude-related aspects, humanistic education developed some practical methods on how to improve learning and development.

5.8.1 The Learning Styles Approach

As in so many other aspects people differ in their learning styles. Each of us has a clear preference regarding our learning conditions. We show differences in the preferred time of day (morning vs. evening people), the method of presentation (visual vs. auditory learners) or the physical and the sociological learning environment (for example individual vs. group instruction).

Students who have the opportunity to learn according to their personal learning style are much better in achieving their learning goals. They can take advantage of their individual strength in the way they approach a learning subject.

To provide these opportunities to their students schools need to know about the individual personal learning styles. Several standardised inventories provide individual profiles of learning styles.

However, identifying the learning style is only the beginning. Significant changes in the behaviour of schools and teachers are necessary in order to respond to the individual styles.

Learning styles-driven schools offer an assortment of various options to the learners. Core subjects are provided at all times of the day in a rotation system. The manner of instruction varies from highly-structured teacher-presented lessons, peer teaching, programmed instruction, computer-assisted instruction to self-learning. Examinations can be taken at a time of the day that is compatible with the biological rhythm of the student. Far more than the traditional school, it stresses students' involvement at all stages of learning and it emphasises problem-solving and creativity.

5.8.2 Cooperative Learning

This approach combines the cognitive and affective aspects of learning. It emphasises participation and active engagement. Cooperative learning is an instructional method in which students work together in small groups - usually four to six students. Each member of the group can participate in a clearly assigned, collective task. They have to work together to achieve a common goal.

Cooperative learning is characterised by the following features:

- It requires fact-to-face interaction among group members;
- Learners must cooperate in allocating resources, assigning roles, and dividing labour. They are related in a positive interdependence;
- Individual responsibility for sharing, cooperating, and learning is assigned to each learner. The learning ensures that goals and rewards are contingent on the performance and contribution of all group members;
- It involves the use of interpersonal and small group skills.

'Cooperative learning'

The advantage of cooperative learning is that it leads to better achievement at all grades and age levels and for all subjects. Furthermore, it fosters cooperation among students with different strengths and weaknesses and of different ethnic backgrounds, ages and sexes.

By cooperative learning the development of team skills is supported as well as the achievement of learning subjects.

5.8.3 Problem-based Learning

Problem-Based Learning (PBL) combines aspects from the learning styles approach and from cooperative learning. It focuses on teamwork, problem-solving skills and self-directive studies. PBL provides knowledge in such a way that it can be better retained and applied more easily in later professional practice.

Problem-Based Learning (PBL) is an efficient way to acquire new knowledge. It shows students the importance of interdisciplinary knowledge for the understanding of problems. Self-study is another characteristic. Students have to organise their learning process. Lectures do not determine what the students have to do. As students have to work partly in groups, PBL supports the acquisition of social skills and the reflection and development of attitudes.

As a consequence, students working with Problem-Based Learning (PBL) are better equipped for problem-solving in actual practice.

For the application of PBL students meet regularly in tutorial groups to work on carefully described problems that arise in professional practice. The tutorial group consists of ten-twelve students remaining together for one block period. They meet twice a week for two hours with the time between the meetings being used for individual studies. Tasks or problems provide the basis for the learning process. To work on these tasks, a particular method is applied: the seven-step-approach.

5.8.3.1 The Seven-step Approach

The seven-step approach is a systematic method to deal with a problem:

Step 1: Clarifying whatever is not clear in the task. The group defines and specifies terms and concepts that are unclear.

Step 2: Defining the problem. The group decides about which phenomena need to be cleared. The task can also be divided into sub-problems.

Step 3: Analysing the problem. The brainstorming technique is applied to find out what group members already know about the problem.

Step 4: Listing possible explanations. The results from the brainstorming session are sorted out and critically surveyed. It becomes clear what still has to be studied.

Step 5: Formulating learning goals. Open questions that arose during the problem analysis need to be answered. This leads to the formulation of learning goals and guides the individual learning process.

Step 6: Looking for additional information outside the group. Based on the learning goals the students have to gather specific information concerning their problem. They can use various sources of information to get the relevant information.

Step 7: Reporting to the tutorial group. Back in the group students discuss the results of their self-study activities. This step corrects deficiencies in knowledge, clears ambiguities and deepens the knowledge of the subject by an active exchange of information. (See Figure 8 showing the cyclic process of PBL).

Problem-Based Learning (PBL) is applied with success at Maastricht University and the Netherlands Aviation College *(NLC - Nederlands Luchtvaart College*) in Hoofddorp, to mention only two examples. PBL considers the latest empirical findings in educational psychology and pedagogy as well as results concerning adult learning.

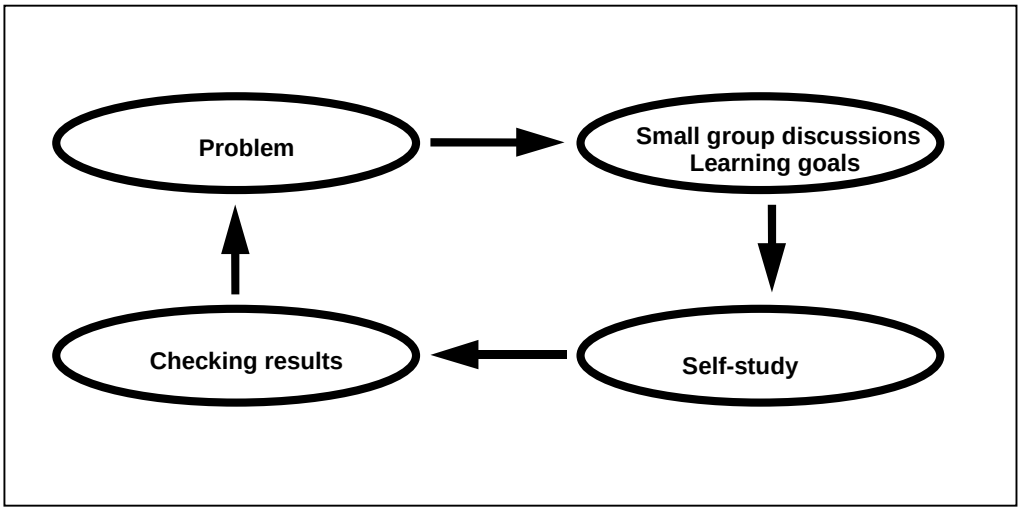


Figure 8: The cyclic process of PBL

5.9 How Adults Learn

As this module is addressed to trainers and trainees in air traffic control we have to take into account that these trainees are adults. Compared to children adults are self-directed and expect to take responsibility for their decisions. Learning programs for adults have to consider this and adapt to the needs of the learners.

Basic assumptions for adult learning are:

- Adults need to know why they need to learn something;
- Adults need to learn experientially;
- Adults approach learning as problem-solving;
- Adults learn best when the topic is of immediate value.

Strategies such as case studies, role playing, simulations, and self-evaluation are most useful for these purposes. Instructors adopt a role of facilitator or resource rather than lecturer in a traditional sense.

Practical principles for adult learning are:

- Adults need to be involved in the planning and evaluation of their instruction;
- Experience (including mistakes) provides the basis for learning activities;
- Adults are most interested in learning subjects that have immediate relevance to their job or personal life.

Adult learning is problem-centred rather than content-oriented.

Three alternative classroom applications that can lead to higher performance of the learners: the learning styles approach, cooperative learning and problem-based learning. The role of the teachers is very different from that of the 'traditional' teachers. Adult students are self-directed and need to be much more involved in the learning activity supported by the instructors as facilitators.

5.10 Summary

Learning can be expressed as a persistent change in behaviour resulting from an experience. There are three main schools of learning.

Behaviourism focuses on observable behaviour but has less application to complex skills tasks.

Cognitivism attempts to describe and explain human mental functions and activities. Understanding how memory works and learning strategies to memorise information help the learners to acquire knowledge.

The Humanistic approach focuses on the uniqueness of people, on the self and on individual development. Orienting training practice towards the needs of the individual and encouraging more control of the learning by the learners may lead to more efficient training.

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6. TRAINING FOR THE FUTURE

6.1 Summary

In Chapter 2, 'Current Air Traffic Control Training Practice', we observed that the inherent conservatism that characterises air traffic control as profession has dictated the way in which people are trained. The minimum content of basic air traffic control training is specified by ICAO together with specific requirements with regard to age, knowledge, experience and medical fitness. Over a period of two or three years student controllers will divide their time between the training institute and an operational unit, progressing through a number of stages terminating at check-out on an operational position. There is a trend to move away from formal examinations but a combination of examinations and long-term assessment may prove acceptable

Chapter 3, 'The Changing Role of the Controllers', drew heavily from the experiences and studies of the CAST project. The introduction of future ATM systems will have an impact on aspects of air traffic control training (content, structure, methods and technologies). CAST identified four areas of change that will affect the job of the controllers (cooperation and teamwork, self-awareness, flexibility and automation) in future ATM systems. New tasks were identified that will challenge the controllers to acquire new skills, especially in the cognitive domain. The existing system of air traffic controller training needs to be appraised, and suitable teaching methodologies adopted to best serve the development and maintenance of these new skills. It is also expected that new functions will arise out of three broad areas of advancement: improved air-ground communication, enhanced aircraft-based systems and computerised strategic ATM aids.

In examining 'Why People Learn' (see Chapter 4) we learnt that human behaviour is not only ascribed to instinct. The historic perspective described pain and pleasure as motivators but this depends on the individuals' point of view or preference. We made the assumption that a state of need is a pain and that satisfying needs is pleasant. These needs can be either physiological or psychological. However, the 'carrot and stick' approach seems today to be limited in its concept. Human motivation is more complex. Historical views of human motivation may help us to understand human behaviour in general but we need to look at more recent studies to have a better appreciation of what motivates people to learn. Understanding and sustaining the intrinsic motivators of learners will help us to provide more effective training. In current training practice the teachers try to motivate the learners. Recent theories show that motivation comes from the learners. Therefore, the teachers facilitate the conditions to help self-motivation.

Chapter 5, 'How People Learn', showed us that learning can be expressed as a persistent change in behaviour resulting from an experience. We looked briefly at three main schools of learning. Behaviourism focuses on observable

behaviour but has less application in complex skills tasks; Cognitivism attempts to describe and explain human mental functions and activities; and the Humanistic approach focuses on the uniqueness of people, on the self and on individual development. When talking about how people learn we need to take account of how our memory works. Memory consists of three interacting parts: the sensory memory, the short-term memory and the long-term memory. Each has a specific function and a defined duration. Sensory memory makes us aware of meaningful information. Short-term or working memory is our 'scratch pad' for thinking. Long-term memory is highly stable and stores information for a long time. Strategies for remembering include rehearsal, organisation and elaboration. Examples of the application of learning styles to the classroom (the learning styles approach, cooperative learning and problem-based learning) illustrated teaching methods that can lead to higher performance of the learners. The role of the teachers is very different from that of the 'traditional' teachers. Adult students are self-directed and need to be much more involved in the learning activity supported by the teachers as facilitators.

6.2 Conclusions

As we saw in Chapters 1 to 3 current air traffic control training is confronted with many changes in the technical area. For that reason it will be necessary to adjust the existing training in order to tackle the challenge of the future technical systems. New training methods and tools need to be applied. But for using new training tools successfully we need to change and adapt our training methods as well. Chapters 4 and 5 imply that modern motivational and teaching methods do already exist and can usefully be applied in air traffic control training.

1. The modular approach of existing training is a step in the right direction, because it allows for more flexibility in learning. It will also be of advantage in managing the changes due to system development (see Chapter 2, 'Current Air Traffic Control Training Practice').

2. These changes will have implications for controller training in training content, the structure of training, training methods and in training technology (see Chapter 3, 'The Changing Role of the Controllers').

3. Training will have to take account of the new systems that will impact differently on the controller population (see Chapter 3, 'The Changing Role of the Controllers').

4. Consideration should be given on individualised instruction and problem-based learning (see Chapter 3, 'The Changing Role of the Controllers').

For adjusting training methods we should make use of the insights of recent research on motivation and learning.

5. The understanding of why and how we learn can help us to design better training and to enable students to achieve a better performance.

Some of the principles described in Chapter 4 on motivation are already well applied in traditional training like praise, or a reward system in the form of grades. What is less considered up to now is the importance of intrinsic motivation. According to the new approaches the responsibility for learning shifts from teachers to learners and the role of the teachers shifts from telling to facilitating. Another relevant source for our motivation to learn, our self-evaluation or self-efficacy, should be taken into account together with the patterns of attribution students use. The trainers should facilitate the conditions that help students to build up a high learning motivation.

6. Understanding and sustaining the intrinsic motivators of learners will help to provide more effective training. (see Chapter 4, 'Motivation').

Many of the principles described in Chapter 5 on learning theories have been experienced by almost all of us in the traditional class room environment. They are an essential part of air traffic control training and will be for the future. But to meet future demands the training should be enriched by modern approaches like Problem-Based Learning (PBL), Individualised Learning Styles and Cooperative Learning. From these new approaches we can expect to increase the performance of the students and enable them to manage future training demands.

7. Orienting training practice towards the needs of the individuals and encouraging more control of the learning by the learners may lead to more efficient training (see Chapter 5, 'How People Learn').

6.3 What Next?

Current and future initiatives for new training policies and programmes would ideally take learners-orientation into account. Learner-orientation, however, puts demands on many aspects of training. A shift from the teaching role into that of the facilitator will require extra effort from air traffic control trainers. The need for easy accessibility of course material and information puts pressure on course developers, style of documentation, library/information access, and the quality and availability of training tools. Students are supposed to discover and understand their preferred learning styles and their roles, strengths and weaknesses in teamwork.

One way to proceed would be to outline which parts of current and future air traffic control training could possibly benefit from a learner-oriented approach. Experiences with learner-oriented approaches to training outside of ATM are available and accessible. With the support of these experiences a first selection of topics in air traffic control training could be made and subjected to development (or re-orientation of existing course material) according to the principles of learner-oriented training. During this experimental phase special attention and evaluation should be given to the role of the teachers, the accessibility of (course) documentation and information and the quality and availability of training tools. It is explicitly implied in learner-oriented training that students should be made responsible for their own results and should be supported in the understanding of their

learning styles and teamwork related abilities. All experiences should be documented and subject to constant evaluation.

A comparison can be made between the performance of learners by comparing the results of such a group with the results of another group of students having undergone 'classic' air traffic control training. Outcomes, feedback and experiences from this experiment would then serve as a basis for further development of the concept of learner-oriented training into wider aspects of air traffic control training. This is a project that could be undertaken in the wider context of training development and harmonisation within the European Air Traffic Management Programme (EATMP).

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GLOSSARY

For the purposes of this document the following definitions shall apply:

Institutional Training: Training that is provided in an establishment designed or designated specifically for training and staffed for that purpose. It comprises 'basic training' and 'rating training'.

Basic Training: Training designed to impart fundamental knowledge and skills to enable student air traffic controllers to progress to specialised air traffic control training.

Rating Training: Specialised air traffic control training to provide knowledge and skills related to a job category and appropriate to the discipline to be pursued in the ATS environment.

Operational Training: Training given in the operational work situation and following institutional training. It comprises 'transition training', 'pre-OJT training' and 'OJT training'.

Transition Training: Phase following rating training during which site-specific theoretical knowledge and understanding will be transferred to the trainees using a variety of methods and during which skills will be developed through the use of site-specific simulations.

Pre-On-the-Job Training (Pre-OJT): Phase of locally-based training with extensive use of simulation using site-specific facilities which enhances the development of previously acquired routines and abilities to an exceptionally-high level of achievement.

On-the-Job Training (OJT): 'Live training' where previously acquired skills and routines are further developed and consolidated under the supervision of a qualified coach in a live situation.

Continuation Training*:* Provision of training related to a job category in order to increase knowledge and skills and/or prepare for new technologies.

Conversion Training: Provision of knowledge and skills appropriate to change in jobs, environment and systems.

Refresher Training: The process of further training in work currently performed in order to improve job performance. As further training given in skills previously acquired but in which the individual may not currently be up to standard.

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ABBREVIATIONS AND ACRONYMS

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

ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
CAST	Consequences of future ATM systems for air traffic controller Selection and Training
CBT	Computer-Based Training
DED	EATCHIP Development Directorate *(EUROCONTROL; no longer exists within EATMP)*
DED5	Human Resources Bureau *(EUROC0NTROL, EATCHIP; now DIS/HUM or HUM Unit)*
DEL	DELiverable
DIS	Directorate Infrastructure, ATC Systems & Support *(EUROCONTROL, EATMP)*
DIS/HUM	ATM Human Resources Unit *(EUROCONTROL; EATMP, formerly DED5; also known as the HUM Unit)*
Doc	Document
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme *(now EATMP)*
EATMP	European Air Traffic Management Programme *(formerly EATCHIP)*
ET	Executive Task *(EATCHIP/EATMP*)
EWP	EATCHIP/EATMP Work Programme
FUA	Flexible Use of Airspace
HMI	Human-Machine Interface
HRT	Human Resources Team *(EATCHIP/EATMP)*
HUM	Human Resources (Domain) *(EATCHIP/EATMP)*

HUM (Unit)	ATM Human Resources Unit *(EUROCONTROL, EATMP; formerly DED5; also known as DIS/HUM)*
IANS	(EUROCONTROL) Institute of Air Navigation Services
ICAO	International Civil Aviation Organisation
LASKA	Learning And SKills Acquisition
MATS	Manual of Air Traffic Services
MUAC	(EUROCONTROL) Maastricht Upper Area control Centre
NLC	Netherlands Aviation College *(Nederlands Luchtvaart College)*
OJT	On-the-Job Training
PBL	Problem-Based Learning
PC	Personal Computer
REP	REPort
RVSM	Reduced Vertical Separation Minima
SARPS	Standards And Recommended Practices
SDE	Senior Director EATMP *(Principal EATMP Directorate; EUROCONTROL, formerly SDOE)*
SDOE	Senior Director(ate) Operations and EATCHIP *(EUROCONTROL, now SDE)*
ST	Specialist Task *(EATCHIP/EATMP)*
TDH Unit	Training Development and Harmonisation Unit *(IANS, EATMP)*
TFCCC	Task Force Common Core Content *(HRT)*
TRM	Team Resource Management
TSG	Training Sub-Group *(HRT)*

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