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HUMAN PERFORMANCE MODELS AND HUMAN ERRORS IN AIR TRAFFIC MANAGEMENT

The models of air traffic controller performance and principles of estimation and prevention of errors in the course of controller professional activity are considered.

Розглянуто моделі продуктивності авіаційних диспетчерів і принципи оцінки та попередження помилок в ході професійної діяльності авіаційних диспетчерів.

Introduction

Air Traffic Management (ATM) is currently under pressure as traffic levels increase. Airspace in many parts of Europe is already complex and congested and there is also pressure from the airlines which are under strong competitive commercial constraints to optimise routes and timings. These issues lead to complexity and time pressure in ATM operations that can subsequently lead to errors.

Additionally, many ATM systems are currently being upgraded and developed into 'next generation' systems which include computerised displays with new functionality and computerised tools. There is also the prospect in the near future of the introduction of datalink technology which will significantly impact the method of operation in ATM.

The purpose of this article is to increase the effectiveness of usage of human performance models and error recording, analysis, and prevention. This work has arisen as a result of the increasing importance of human error, error recovery and error reduction in ATM. In particular, the analysis in ATM is becoming more important as traffic levels increase as European airspace becomes more harmonised and as ATM operational centres make more use of computerised support and automation.

Human error is a potential weak point in the ATM system and, therefore, measures must be taken to minimise errors and their impact, and to maximise other human qualities such as error detection and recovery.

Theories of human error and practical approaches to analysing and managing error have largely been developed in other industries such as chemical and nuclear power industries. In these industries the effects of human error have already resulted in numerous incidents and accidents. These have resulted in a large body of knowledge on a number of issues, such as what errors occur, how and why they occur, and how they can be prevented or guarded against. ATM can borrow from this knowledge to develop an ATM-specific approach.

Human error in Air Traffic Management

Human error is a major contributor to ATM incidents, with some reviewers suggesting that the human error contribution is in the order of 90% or more. Most industries have similar human error contributions (e.g. nuclear power - 70-90%). Controllers handle heavy air traffic every day without major incident, and still the ATM system remains highly reliable.

However, the fact that almost all incidents do involve human error is still on record. Hence, if such errors could be reduced, or the system made tolerable to them, there would be large increases in safety, with the additional potential for significant ATM capacity gains.

While investigation of incidents in this environment often conclude human error as the main causal factors, investigation of the human performance factors aims to go beyond this category alone, analysing the different facets of the situation and trying to understand the mechanisms and context which led to the error.

The idea of personal responsibility is rooted in western culture and the occurrence of a human-made accident leads inevitably to a search for the human to blame. Given the ease with which the contributing human failures can subsequently be identified, such people are not hard to find. One of the obvious consequences of assessing human error in this environment is that in understanding how and why it happened we may be able to prevent similar events. This process is not concerned, therefore, with the attribution of blame, but rather the analysis of the error and its underlying factors which will help our understanding of human performance and therefore give us the opportunity to recover and manage these occurrences in future.

The need for a model-based approach

Air Traffic Management is therefore ready for the development of a methodology that allows a better understanding of human error and the opportunity to learn from these situations. Furthermore, since errors and the incidents arising from them are relatively rare, the best way to learn from such errors is to enlarge an error 'database'. Since European ATM is becoming more harmonised, working collaboratively with its neighbours, much more will be learned about errors if all States use the same approach.

If a methodology can be developed that can be applied to any European ATM situation, the European ATM organisation as a whole and each individual Member State can maximize learning from all human error events and incidents. This should make the ATM system safer and more effective.

At this stage it is necessary to explain exactly what is needed in terms of an error analysis because, to some extent, every European State will already have some means of recording, classifying, and learning from human errors in ATM.

The development of a new European system for analysing incidents may be seen as an implicit criticism of existing approaches. The question that should be addressed is why current approaches may not suffice and, therefore, why a new approach is necessary.

The model-based approach has some intrinsically desirable properties. Most importantly, a model allows causes and interrelations between causes to be better understood. An error model provides an "organising principle" to guide learning from errors. Trends and patterns tend to make more sense when seen against the background of a model, and more "strategic" approaches to error reduction may arise, rather than short-term error reduction initiatives following each single error event. This will be particularly important as new tools and functions or procedures are introduced across Ukraine.

Models also need precise definition so that practitioners can agree a common set of terms and meanings. This precision also has the advantage that different users will tend to classify the same events in the same way, thus ensuring a consistent and accurate picture of where problems originate.

Therefore, a model-based approach has certain advantages in terms of understanding the errors and being able to learn from them and in terms of increasing the effectiveness of error analysis. The development of a model based approach that also incorporates the vast experience that has been accumulated by existing operationally-based systems would represent a valuable tool that can significantly protect ATM from human error.

Models of human performance and error

Despite the dominance of human error in ATM-related incidents there are few specialised human error classification systems to analyse and classify ATM errors. Many error classification systems already exist but most of these are either generic in nature or have been developed for nuclear industries. These systems range from simple lists of error types to classification systems based on a model of operator performance.

Unfortunately, many of the existing systems do not adequately identify the errors that can occur in ATM, such as errors of judgement, hearback errors and visual misidentifications. Furthermore, some systems are based on models of performance that do not represent ATM tasks.

The absence of useful human error taxonomy also creates difficulties in learning from incidents. A "tailored" classification system for ATM would have practical value in gaining deeper insights into the causes of incidents and in suggesting measures to provide error prevention, protection, and mitigation.

There are currently no widely accepted models of human performance and human error in ATM for the following reasons:

– ATM is associated with several "covert" cognitive skills or activities such as pattern recognition, situation assessment and awareness, judgment, projection, and prospective memory. These can be difficult to represent in an ATM model;

– ATM differs in different functional areas and different countries, so specific ATM models may have low applicability.

Air Traffic Management changes over time, with new technology and new ways of working. Therefore, ATM models could become obsolete.

Fortunately, several generic models and theories of human performance and error exist, which have been widely accepted.

These provide a general framework for classifying and understanding specific errors based on human characteristics such as behavior, psychological processes and task characteristics.

Most models of human performance are elaborated on the basic "input-organism-response" model of human performance, which is analogous to models used for a physical component (fig. 1) [1; 2].

Note that there is no one-to-one relationship between external task performance and internal human functions. Error mechanisms and failure modes depend on mental functions and knowledge which are activated by external events.

Mental functions and human factors cannot be observed but must be inferred from characteristics of the task and work situation together with the external manifestation of the error. This model must relate elements of human decision-making and action to internal processes, for which general psychological mechanisms and limitations can be identified.

Source, Message, Channel, Receiver (SMRC) Model adds a sociological slant to the Model of Communication.

It suggests that successful communication depends upon a match between the skill and attitudes of the source and receiver.

This knowledge must be acknowledged, and the significance of culture and social systems are emphasised. SMCR Model of Communication is shown in fig. 2 [3].

The model emphasises the role of uncertainty in human performance – behaviour is not only a function of what happened but also the one of what could possibly happen.

The model was constructed as a part of mathematical theory of communication which could be applied to a wide variety of information transfer situations, involving humans, machines, or other systems.

This model depicts the pilot-ATC communication loop and contains cultural, linguistic and technical factors that may result in communication breakdowns in the present aviation system. It may be noted that, in principle, the pilot could also be the sender, and the controller could be the receiver. Furthermore, the model could be used to describe the communication between two controllers.

The Model emphasises environmental or contextual factors. It also stresses the transactional nature of the communication process in which messages and their meanings are structured and evaluated by the sender, and subjected to reconstruction and evaluation on the part of the receiver while interacting with factors within the environment (fig. 3) [4–7].

Also a broader approach regarding communication was proposed including a categorisation communication types within organisational practices. This approach captures sociological problems which have an important influence on the safety health of aviation organisations.

Three types of communication styles which produce different organisational climates are described as Pathological, Bureaucratic and Generative. These varying organisational climates handle safety information quite differently and are summarised in table.

Types of organisational practice

Generative Culture	Bureaucratic Culture	Pathological Culture
Actively seek information	Information may not be found	Information is not wanted
The messengers are trained	The messengers are listened to if they arrive	The messengers are "shot"
The responsibility is divided	The responsibility is shared	The responsibility is avoided
The organisation inquires and implements reforms	Failures lead to local repairs	Failure is punished
New ideas are welcomed	New ideas often present problems	New ideas are actively discouraged

The generative culture is obviously the type of approach which should be the goal in a safety critical organisation. In these groups, hidden failures are actively sought and, if possible, removed. However, this can only be successful if the management not only encourages all levels to communicate but also promotes all personnel to critically evaluate all levels of operation.

These organisations also develop effective ways of reporting problems, and deal positively with errors; the system learns through its mistakes and rather than punishing those that are involved in the error chain, they use these events to improve the safety health of the group.

PHYSICAL COMPONENT

Input → Transfer functions → Output
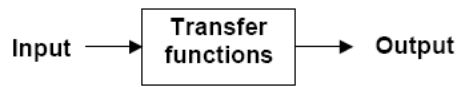
Characterised by: - failure modes and probabilities
                     - environmental factors

HUMAN OPERATOR

Input → Perception → Mediation → Motor functions → Output
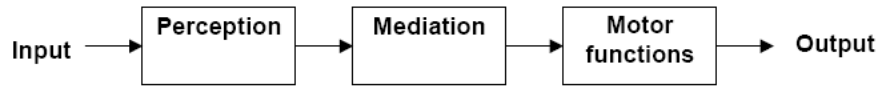
Characterised by: - error modes and probabilities
                     - Performance Shaping Factors (PSFs)

Fig. 1. Schematic diagrams for failure analysis of physical components and human operator
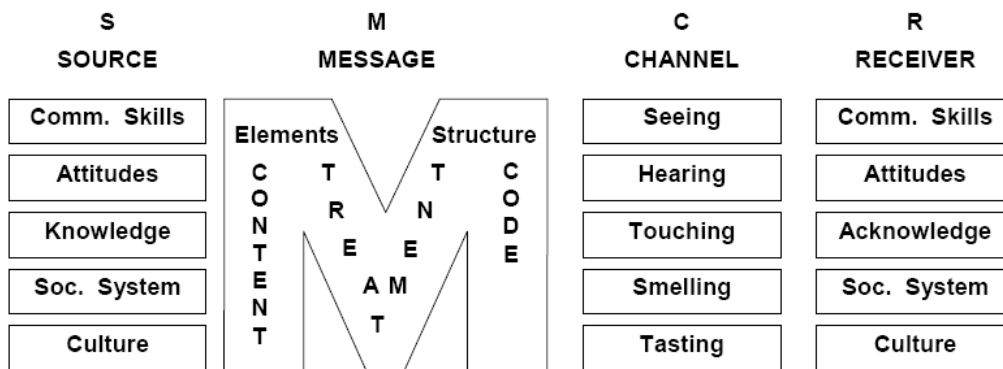
S SOURCE	M MESSAGE	C CHANNEL	R RECEIVER
Comm. Skills	Elements / Structure	Seeing	Comm. Skills
Attitudes	CONTENT / TREATMENT / CODE	Hearing	Attitudes
Knowledge		Touching	Acknowledge
Soc. System		Smelling	Soc. System
Culture		Tasting	Culture

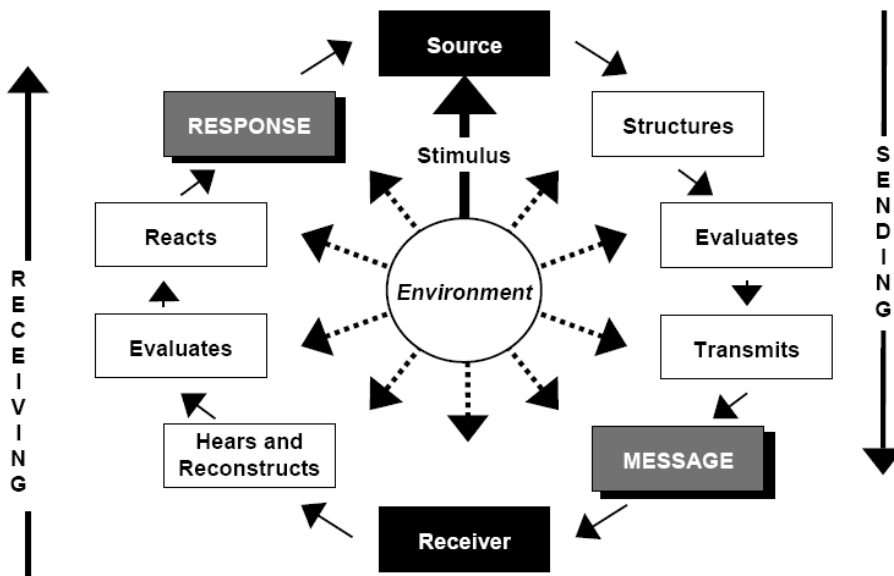Fig. 2. Source, message, channel, receiver model of communication

Fig. 3. Model of Communication (adapted)

Conclusion

The article represents an extensive review of the relevant models of human performance, human error theories and taxonomies, and conceptual frameworks from several diverse theoretical areas and industrial domains.

Different approaches to performance modelling and error analysis from several traditions, such as early taxonomies of error modes, communication models, information processing, symbolic processing, errors of commission and cognitive simulations are described in the article.

The review finds that human information processing is the most appropriate model for an ATM error taxonomy. However, the other approaches reviewed will significantly influence the developing taxonomy.

When taken together, this combination of human error and performance modelling research, techniques and frameworks from other industrial domains, new developments, and ATM context lead to a new conceptual framework for error analysis in ATM. This includes:

– a model of human information processing;

– contextual factors such as classifications of task, equipment and information;

– a flowchart format to create a structured technique.

These major shifts in work practices will affect both controller and pilot performance, and new opportunities for error could arise, particularly in the "transition period" during which new systems and practices are introduced.

These developments suggest that the ATM system is at the beginning of a long period of significant change and evolution, a period that will possibly see increased error rates and potentially new errors. This indicates a need for the development of an approach to better understand errors and monitor error trends.

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