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The Investigation of Human Error in ATM Simulation

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Abstract

This report is the first in Phase 2 of the 'Human Error in ATM' Project (HERA 2). It concerns the further development and investigation of human error, its prediction, detection and management within the Air Traffic Management (ATM) system. The purpose of the work is to assess how human errors are generated within a simulated ATM environment and, more importantly, how they are managed. This report not only discusses the errors found in these situations but also offers a methodology for future work in the ATM system.

Keywords

Human Error | Human Performance | Error Management | Risk Assessment

Simulation | Performance Adjustments | Performance Deviations

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EXECUTIVE SUMMARY

The general objective of the 'Human Error in ATM (HERA)' Project is to investigate several specific areas associated with the prediction, detection and management of human error in Air Traffic Management (ATM), and to develop methods for the implementation of the results of these concepts at various levels of the air traffic safety management within Europe.

Phase 1 of the HERA Project (HERA 1) produced a detailed methodology and technique for analysing and learning from error-related incidents in ATM (see EATMP, 2002a, 2002b, 2002c and 2002d).

The objective of HERA Phase 2 (HERA 2) is to explore more intensively the potential operational applications of this error analysis technique, in relation to four specific safety-related areas:

- to develop an approach using the HERA Technique to investigate how human error can be detected and managed within a real-time simulated Air Traffic Control (ATC) environment;

- to investigate the potential of the HERA classification as a prospective tool within ATM (error prediction);

- to develop an approach using the HERA classification technique for safety management within ATM;

- to develop a training course on the HERA analysis technique for incident investigators and safety managers within several ECAC States.

This report deals with the first of these four objectives: human error observation in a real-time simulated environment and analysis with the HERA Technique. It presents the results of this study in two parts:

- firstly, the development of an initial observation methodology based on the HERA Technique, for capturing ATC errors and related performance, in a simulation environment at the EUROCONTROL Experimental Centre (EEC), Bretigny, France;

- secondly, the development of a more robust error recording and analysis methodology based on both the results of the first exercise and the HERA Technique, for capturing data in a second simulation environment within a European State.

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1. INTRODUCTION

1.1 The HERA Project

Phase 1 of the 'Human Error in ATM' Project (HERA 1) sought to review theories of human error and formulate a practical approach for analysing these errors within the ATM environment. This work arose as a result of increasing automation and the importance of error recovery and error reduction in ATM as the future traffic increases are predicted and as airspace structures are re-aligned to produce maximum traffic flow. The resultant work in this first phase established the rationale for a conceptual framework for this initiative. This conceptual framework outlined a model of human performance and the types of taxonomies that would be required to classify errors and contextual factors relating to ATM incidents (see EATMP, 2002c). This technique was then used in various validation exercises to establish its robustness, efficacy and usability (see EATMP, 2002d).

Reliability and variations in human performance are an important element in the understanding of aviation safety and in analysis and design of air traffic management systems. The first phase of the project established a framework for understanding human errors in ATM operations and has provided a basis for better categorising air traffic management incident data. Statistics and trends obtained from applying these concepts have provided a basis for the application to a range of ATM activities such as incident analysis and, to a lesser extent, the prediction of human performance with new ATM tools. However, the dearth of similar work indicated that there was a need to extend this activity into another dimension, that of prediction, detection and recovery of human error within the ATM system.

The general objectives of the second phase of the HERA Project (HERA 2) are to investigate several specific areas associated with the prediction, detection and management of human error in ATM, and to develop methods for the implementation of these concepts at various levels of the ATM system, such as safety training, safety management, incident investigation and the application of human error vulnerability within the system.

The specific objectives of HERA 2 are therefore the following:

1. To develop an approach to investigate how human error can be detected and managed within a real-time simulated ATC environment.

2. To investigate the potential of the HERA classification as a prospective tool to predict error-prone conditions within ATM.

3. To develop an approach using the HERA classification tool for safety management within ATM.

4. To develop an approach, using the HERA classification, for the training of incident investigators, which incorporates an understanding of human factors and system safety aspects within the investigation process.

1.2 Overall Work Plan and Focus of this Report

The overall work plan for this part of the HERA Project (HERA 2) is divided into four Work Packages (WPs), which reflect the objectives cited in the previous paragraph in Section 1.1. Although the four WPs will be explored separately, they typically have heavy dependencies. Figure 1 illustrates the inter-dependencies of each objective and WP, and their link with the HERA 1 work.

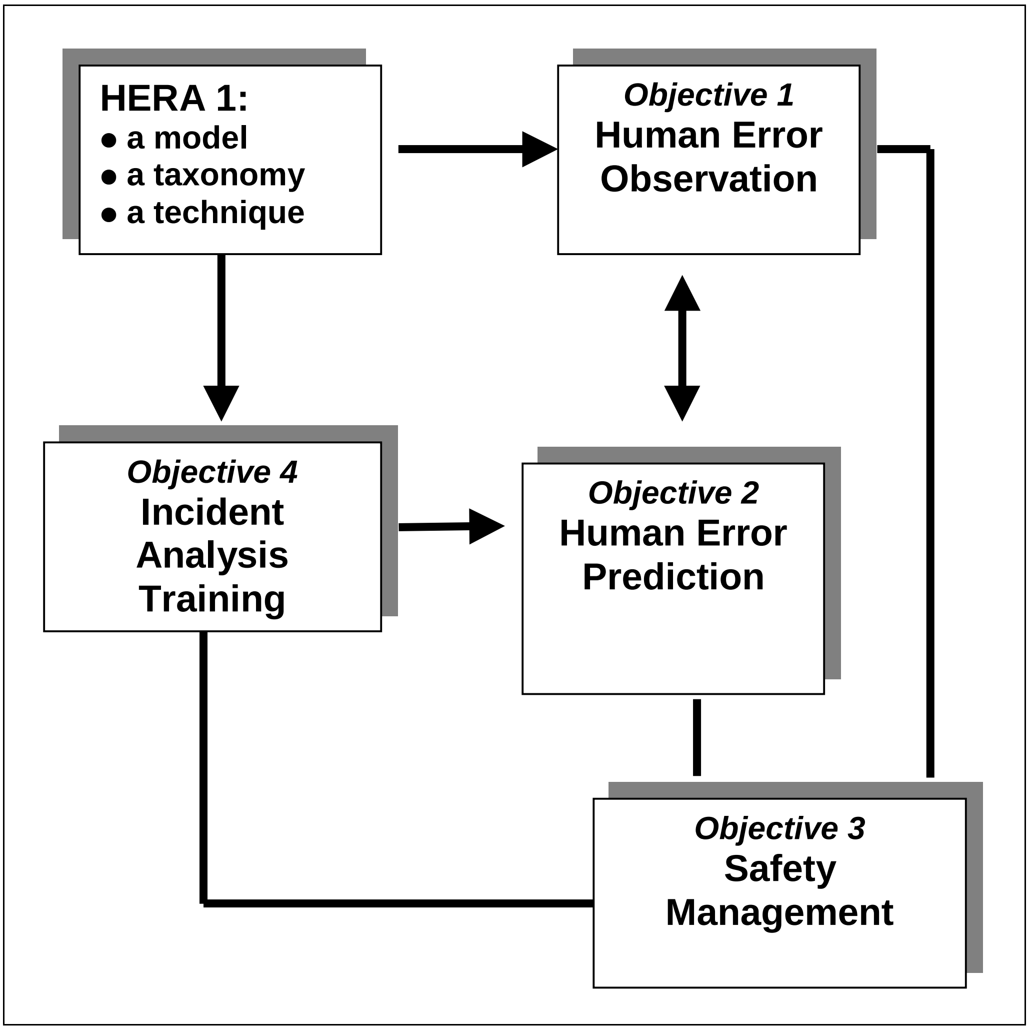

Figure 1: Overall work plan for Phase 2 of the HERA Project (HERA 2)

The present WP1 of HERA 2 describes the development of an approach to investigate which human errors are made (using the HERA Technique), how they are made and when they are detected and managed within a real-time simulated ATC environment.

The report describes a two-stage approach in this investigation process:

- firstly, observations were made in a real-time simulation environment with both human factors and ATM experts using several tools and the HERA Technique as described in Phase 1 of the HERA Project (HERA 1);

- secondly, the lessons learned from the first investigation were used to support the second observations used in a second real-time simulation.

Results from both these experiences are detailed and recommendations for future work are discussed.

The remainder of this report contains three chapters:

- Chapter 2 details the observation method that was used in the first of the simulation exercises. The results of these first observations are presented as well as the lessons learned for the improvement of the observation method.
- Chapter 3 develops the ideas gained from the first simulation and applies these methods to the second simulation. The results of the second observation simulation are then reported.
- Chapter 4 presents the conclusions of this study in terms of a theoretical framework for human error observation and application of the HERA Technique.

The Appendices to this document present the detailed data collected during the two simulations.

An additional document, 'The Investigation of Human Error in ATM Simulation - The Toolkit' (EATMP, 2002e), details all the methodologies and support materials required to follow a similar experimental project in ATM simulation.

1.3 Human Error Observation in ATM: A Theoretical Perspective

The first influential books and papers on human errors (Norman 1981; Reason, 1979, 1984) date back the eighties. The distinction between routine errors (slips and lapses) and mistakes is amongst the oldest and robust experimental work in this field, and follows the advances in studies on attentional processes.

Research continued in the nineties and progressively focused on the role of errors in accidents (Reason, 1990). New concepts such as organisational safety emerged from these approaches, as well as a new modelling of the ecological role of error in cognition. The most significant results of this decade are described below.

The human contribution to errors has been frequently assessed as between 70-90% (Kinney, 1977; FAA, 1990; Reason, 1990) and the error rate in dynamic situations such as flying, driving and anaesthesiology has been repetitively found to be approximately two or more per hour (Amalberti, 2001; Helmreich, 2000; Leape, 1994). However, these seemingly high error rates hide the fact that humans are exceptionally good at detecting, controlling and managing the risks associated with these errors (Allwood, 1984). These issues support the well-known fact that very few errors or error chains actually result in an accident.

Research in ecological psychology (Flach, Hancock, Caird and Vicente, 1995; Zsambok and Klein, 1997; Amalberti, 2001) indicate that human behaviours such as poor decision-making, situation assessment and the reluctance to recover error, are in fact adaptive behaviours aimed at a compromise between the costs and benefits in complex demanding situations. Any assistance from machine systems aiming at assisting some tasks and consequently suppressing this natural behaviour could paradoxically result in an inappropriate division of attention or excessive workload, with the consequence of new and uncontrollable errors (Noizet and Amalberti, 2000). In other words, the cognitive control of situations, particularly in such environments as air traffic control, demands a continuous compromise of different issues such as available time, task priorities, and available resources.

When considering the categories of errors in dynamic systems, violations appear to be as frequent as classic routine errors and mistakes (Reason, 1990). Although no evidence is available on this issue in the ATM environment it is known that violations represent 54% of the overall errors observed on the flight deck, (Helmreich, 2001). Pollet et al (in press) indicate that there are two issues which are represented in this behaviour, firstly the need to complete the task and secondly individual benefit.

1.3.1 Errors in Air Traffic Management

Evaluations of the error rate of Air Traffic Controllers (ATCOs) under normal operational conditions have not been published, although errors as such have been the subject of some research (EATMP, 2002c).

Data from a large European country indicates an average of a hundred serious safety events per year in air traffic control. After closer examination only about ten out of these hundred events effectively called for national safety actions and only one accident was partially attributed to air traffic control system over the past five years. However, these data are only the ‘tip of the iceberg’ of real error occurrence. Finding out the true error rate in normal operations and understanding the nature of the connection between error occurrence and those errors with negative consequences illustrates a real conceptual challenge.

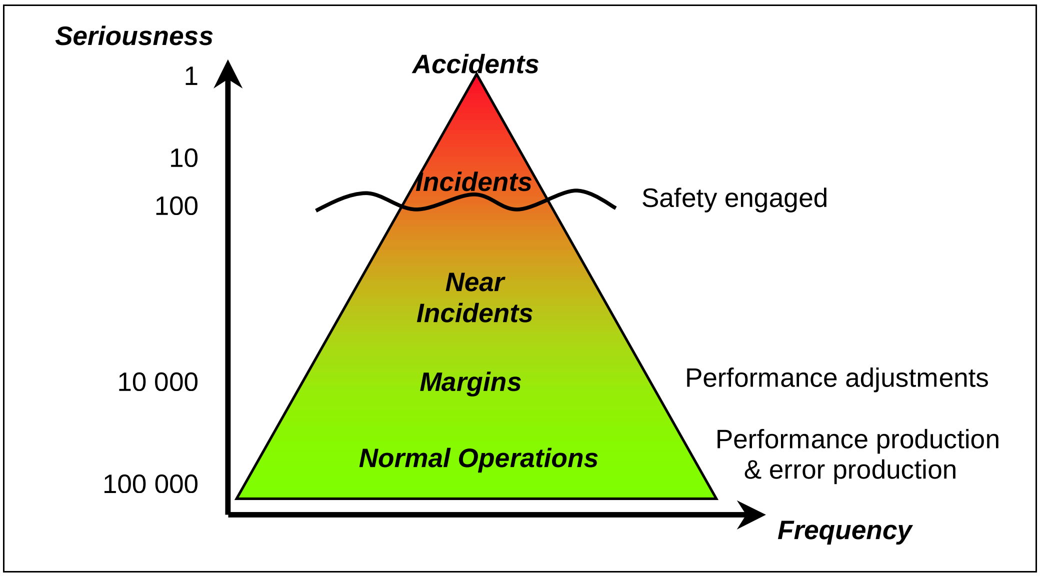

Figure 2: The relationship between seriousness and frequency of occurrences

It is reasonable to say that it takes about a thousand occurrences for an error to emerge, that is to have adverse consequences (100 out of 100,000). It is only when the error is committed in a specific context that the risk can be ascertained.

With the growing traffic rates the risk of accidents could grow following a non-linear profile. Therefore, it is essential that the nature of human error should be evaluated in the operational setting. Only field observation can help to model this error behaviour and examine the way in which controllers assign risk and recovery in their working environment.

1.3.2 Observing errors in the ATM environment

The characteristics of errors and their management, being cognitive in nature, make their observation very difficult. The problems are fourfold:

⇨ Firstly, the result of observation depends on the definition of error given to the observer. The definition of error in HERA is as follows: "Action (or inaction) that potentially or actually results in negative system effects". This definition is based on the error outcome and focuses the observation on an action or inaction which has problems if the observers are not in a position to discuss the error events with the controller. Difficulties also occur that are related to the evaluation of the negative system effects:

- some negative consequences may occur without being linked to an error;
- many errors tend to be ignored by the observer when they are recovered soon after their production;
- some errors tend to be ignored when there is an uncertain evaluation of their consequence in the long term.

⇨ Secondly, direct action errors and violations are much easier to observe than tactical and strategic errors. Expertise of the observer in the domain observed (ATCO expertise in ATM) is necessary to detect strategic errors.

⇨ Thirdly, the control of the situation requires the control of errors, but the control of errors is, as described above, the result of a continuous compromise that emphasises error detection and recovery rather than error avoidance. The pragmatic consequence is that error observation should include error management (detection, recovery, management), which adds multiple challenges to the observers activity.

⇨ Lastly, the topic of error is extremely sensitive for most professionals. The key to obtaining quality data is to ensure the subjects are confident of the motivation of the observers and that the observations will in no way jeopardise their future work.

1.3.3 Observation of Human Errors in ATM Simulation

The observation methods developed were refined from a series of two observation exercises in real-time simulated environments:

- a simulation associated with the Free Route Airspace Project (FRAP) at the EEC during September 2000;

- a simulation which was held in a European simulation centre during May 2001.

The detail of these two simulation exercises is described below, followed by the conclusions derived from the first series of observations which were used to refine the observation method implemented in the second observation exercise.

2. THE FIRST SIMULATION EXERCISE

The first simulation exercise was associated with the Free Route Airspace Project (FRAP) and organised in September 2000 in the EEC. The objective of the FRAP simulations was to assess the impact of flights using free route airspace on the coordination between civil and military air traffic control sectors.

2.1 Free Route Airspace Concept

Because of the increase in capacity demand, Free Routing (FR) is being proposed as one means to accommodate this predicted growth in flights. Under FR aircraft in upper airspace would be permitted greater flexibility in flying direct routes (i.e. without reference to the current ATS network) than is currently the case. The Free Route Airspace Concept envisions keeping the current route structure below the free route altitude and upon entering free route airspace, aircraft would be cleared to fly direct requested routes between free route entry and exit points.

The following simple diagram (Figure 3), depicts the principles of structured and FR in en-route airspace.

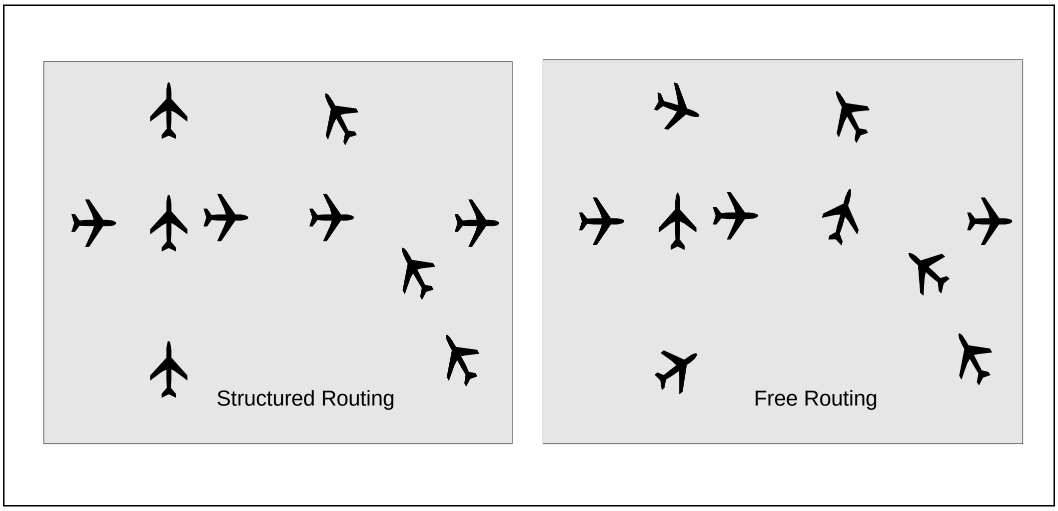

Figure 3: Separation of aircraft under structured (left) and free routing (right)

Under free route airspace, monitoring for losses of separation may be a more complex task for the controller.

The FRAP simulation environment therefore had specific features that could impact on the present data gathering process:

- the goals of the FRAP simulations were to test several types of changes in procedures and airspace organisations to assess their advantages and constraints;

- the Human-Machine Interface (HMI) used for the experimentation had additional features which some controllers had not used before including automatic coordination between sectors and electronic flight strips;

- the task sharing and responsibilities between the Radar Controller (RC) and the Planning Controller (PC) was predicted to be less structured.

2.2 Free Route Airspace Exercise

One day of training and familiarisation with the FRAP environment was necessary for the observers to understand the FRAP logic and learn the HMI dedicated to the simulations, before starting the observations.

The simulation program was organised with a shift of eleven controllers: CAA Belgium (one), CAA Sweden (one), CAA Finland (one), Maastricht (two), Belgian Air Force (four), Netherlands Air Force (two). Ten controllers were working on the simulations at any one time whilst one had a break.

The choice of the controllers (three) was dictated by the choice of the position to be observed, although all controllers volunteered for this exercise.

The profiles of the controllers observed can be seen in Table 1.

Table 1: Profiles of the observed controllers in the FRAP simulation

	Controller 1	**Controller 2**	**Controller 3**
Age	34	54	50
Usual working place	Maastricht	Tempere / Finland	Dutch Mil / The Netherlands
Civil / Military	Both	Civil	Military
Experience in ATC	14 years	31 years	23 years
Experience on the HMI	2 weeks	5 weeks	2 weeks
Experience on the sectors	South: 2 weeks North: several years	2 weeks	23 years

2.2.1 Free Route Airspace Methods

The observation protocol that was designed for the first observation exercise was based on the experience gained in error analysis. The method contained two main phases described as follows:

Phase 1: Observation

One position Radar Controller (RC) was observed by two individuals; one observer was an experienced controller with some human factors knowledge and the second was a cognitive psychologist with limited air traffic control knowledge. The ATCO observer was seated beside the RC and the psychologist observed the situation from behind, but in view of both the radar screen and recording monitor. Both observers could listen to the communications on the frequency between the observed RC and the pilot, but only the ATCO observer could hear the communications between the Planning Controller (PC) and the RC.

Using the HERA definition of an error and the classifications, the two observers recorded as many errors and detection/recovery strategies as possible by taking free notes on paper, with a time code reference of their observations.

The situation itself was recorded with two video cameras. One camera behind the radar and planning controllers was recording the radar screen whilst another camera from the side was filming the RC's profile which included communication with the PC.

Phase 2: Debriefing and auto-confrontation interviews

After the simulation session, the RC was interviewed by the two observers, with the support of the video recordings (synchronised on one single screen). Auto-confrontation meant that the observed controller was faced with the video recording of the simulation session and asked to comment freely about what happened. This technique was more active since direct questions were asked to the observed controller in order to gather specific elements of information about the observations made.

The interview was audio recorded and free notes were taken by the two observers.

2.2.2 Free Route Airspace Results

Results of the observations

121 observations were gathered over the three observation sessions, using the method described above. These results are summarised in Table 2.

Table 2: Results of the errors observed

Simulation session	ATCO	Psychologist	ATCO and psychologist	Total
S1	41	15	4	52
S2	24	13	2	35
S3	11	24	1	34
Total number of observations	76	52	7	121
Total in percentage	**62.8%**	**43%**	**5.8%**	**100%**

The observers took note of all issues which they perceived as erroneous events. In many cases this was not only an observed error as HERA would classify, but it also included notes relating to their lack of understanding of the situation, deviations from their expectations and deviations from procedures. This resulted in observations that could be classified into three types:

- ‘events’ that occurred at a specific time (i.e. ‘warning from the adjacent sector’);

- ‘states’ of an aircraft or of a system (i.e. ‘wrong exit level’) related to potential errors and

- ‘actions’ performed by the controller (i.e. ‘transferring a plane’) that were actual errors or potential deviations.

The ATCO and the psychologist observed not only different erroneous events but also a different number of these events. The ATCO observed almost 63% or 76 events of the total 121, whilst the psychologist observed 43% or 52 events; only 5.8% or seven events were common to both.

The ATCO observer had a more accurate view of the technical situation, which included appropriate expectations and a better understanding of the airspace and traffic, as well as a frame of reference that facilitated the detection of deviations. He saw more strategic errors, errors due to poor situation awareness and errors linked to operational problems. More explicit action errors, such as slips with the input device and communication mistakes, were seen by both the observing ATCO and the psychologist.

Results of the interviews

From the 121 noted observations, 28 observations were questioned in detail as ‘outstanding events’ during the interviews.

The nature of the information collected between the three interviewees was quite variable. The personality of the controller observed greatly influenced the information collected; some controllers were more talkative and cooperative in terms of their openness with respect to errors and their own ways of working.

The explanations provided by the observed controllers were also of a different nature, depending on whether they focussed on a precise action error, a specific set of errors or a situational context which was difficult to handle.

Typically, the interview process was also limited by the complex nature of some of the data or by unexplainable information, particularly concerned with the contextual conditions which had led to the errors.

In spite of these difficulties, the interviews provided a very valuable feedback from the observed controller about how the simulation session was perceived, which difficulties were handled, and how strategies were chosen and why certain errors were made. This significantly enriched the understanding of the initial observations.

Post-interview analysis

The data review was conducted by a team of psychologists after the interview sessions to produce a ‘cleaner’ record of the observations made. It appeared that the information collected during the interviews made it possible to distinguish between those observations considered by the observed controller to be actual errors or behaviour which was intended to manage the error event. The explanations provided by the observed controller either changed the initial understanding of the observation or confirmed the assumptions made by the observers in taking note of the event. Other assumed errors appeared only to be the observable consequences of errors that had been committed previously, therefore new errors emerged that had not been taken into account.

Results of the HERA analyses

HERA analyses were performed by a team of psychologists with 24 ‘outstanding event’ observations which were suitable.

Table 3: Summary of the HERA analyses

N°	ETs[1]	EDs[1]	EMs[1]	IPs[1]	CCs[1]
1	Action too early (earlier transfer)	-	-	-	FRAP context
2	STCA	-	-	-	FRAP context
3	Action too late (late transfers)	Memory / Planning and decision-making	Prospective memory failure / Late decision or plan	Cannot be determined	FRAP context
4	STCA	-	-	-	FRAP context
5	Action too late (late transfers)	Memory / Planning and decision-making	Prospective memory failure / Late decision or plan	Cannot be determined	FRAP context
6	Wrong exit level / Wrong next sector	-	-	-	FRAP context
7	Wrong exit level / Wrong next sector	-	-	-	FRAP context
8	Wrong action on right object (transfer to a wrong sector)	-	-	-	FRAP context + lack of equipment/ information + Motivation/morale (personal factors)
9	Input error	Cannot be determined	Cannot be determined	Cannot be determined	FRAP context
10	Omission (unidentified caller)	Perception and vigilance	Not decidable: Misidentification; Misread; Visual misperception; No identification; Late identification	Vigilance failure	FRAP context
11	Omission (unidentified caller)	Perception and vigilance	Not decidable: Misidentification; Misread; Visual misperception; No identification; Late identification	Vigilance failure	FRAP context
12	Omission (undetected potential conflict)	Perception and vigilance	Cannot be determined	Vigilance failure	FRAP context
13	Action too late (late transfers)	Memory / Planning and decision-making	Prospective memory failure / Late decision or plan	Cannot be determined	FRAP context
14	Action too late (late transfers)	Memory / Planning and decision-making	Prospective memory failure / Late decision or plan	Cannot be determined	FRAP context
15	STCA	-	-	-	FRAP context
16	Omission OR Violation (no replying to a pilot)	-	-	-	FRAP context
17	-	-	-	-	FRAP context
18	Omission (tag incoherence)	-	-	-	FRAP context
19	-	-	-	-	FRAP context
20	-	-	-	-	FRAP context
21	Omission (undetected changes in plane's direction)	Perception and vigilance	No detection (visual)	Not decidable: Perception discrimination failure OR Out of sight bias	FRAP context + other pilot-controller communication problem
22	Problem with an aircraft request	-	-	-	-
23	Omission (conflict trajectories)	Perception and vigilance	No detection (visual)	Cannot be determined	FRAP context
24	Input error	Response execution	Selection error	Manual variability	FRAP context

[1] ETs: Error Types – EDs: Error Details – EMs: Error Mechanisms – IPs: Information Processing levels – CCs: Contextual Conditions.

The HERA tables and flowcharts were used successfully when the analysed error, as well as its surrounding context, could be reconstructed from the interviews.

2.3 Lessons Learned from the First Simulation Exercise

The main lessons learned for the improvement of the observation methodology are listed below.

1. Data collected

Since the FRAP environment did not provide a stabilised frame of reference, errors were very difficult to identify for external observers. They mostly depended on the interpretations and strategies of the controller rather than on any precise expected practice or result.

> *In order to collect more reliable data on ATCO errors, a more stabilised observation platform should be used where the practices of the observed controllers are as close as possible to their daily practices in a real control centre.*

Not all events could be analysed using the HERA Technique.

> *To allow for the complete analyses of errors using HERA it is necessary to find a way of gathering systematically the basic data required by the HERA Technique (task, equipment, information, error details, contextual conditions). The data collection method should consider the HERA classifications both during the video recording and in terms of interview so that the reconstruction of the whole context can be captured.*

2. Expertise of the observers

The ATCO observer was able to see more events than the psychologist. While the psychologist was, in most cases, waiting for the visible consequences (procedure deviation) and/or associated verbalisation to qualify an event, the ATCO detected events in a more proactive way, even in the absence of any verbalisation. Moreover, a significant part of the strategic errors could only be seen by the ATCO. Therefore, a significant technical background is desirable for the technical observations. However, in the interview situation the psychologist who was more skilled and experienced in human performance was more effective.

The ATCO and psychologist have complementary fields of expertise. The ATCO should be the main observer at the technical recording stage, but the psychologist should be present to keep a record of the overall situation. The psychologist should be the main interviewer, but the ATCO should also be present as a support to assist in the area of operational explanation and expertise.

3. Auto-confrontations and interviews

These appeared to be very beneficial and absolutely necessary to understand the nature of the errors noted and to confirm the assumptions made. However, it should be noted that the quality of video and audio recording must be considered before the data gathering process.

Special attention should be paid to the video recording of the sessions, in order to obtain good quality data.

There was little time available for the ATCO and the psychologist to discuss their observations and prepare the interview with the observed controller. Since it is advisable that the interview should be led by the psychologist, a detailed transfer of understanding of the observed session should take place prior to the interview with the observed controller.

Time should be allocated for the two observers (ATCO and psychologist) after the observation session to debrief on the observations and prepare the interview thoroughly.

A systematic questioning method should be worked out to overcome the difficulties mentioned, the goal being to encourage the observed controller to describe in detail their activity and to explain it pragmatically.

The second simulation exercise took the lessons learned from the FRAP simulation and attempted to improve, not only the methodology used for error recording, but also control for those variables which proved difficult in the first simulation.

3. THE SECOND SIMULATION EXERCISE

The second simulation exercise was related to the testing of changes within airspace sectorisation, in a European country, from those which were currently used. Three control centres were involved in these simulations: two approach control centres and one en-route control centre.

3.1 Airspace Sectorisation Exercise

Two days were spent at the simulation centre with the technicians, the observers and the people responsible for the simulations prior to the observations for familiarisation and training purposes. It was decided to observe two different positions (one approach position and one en-route position), with two ATCO observers and two psychologists.

An additional day was spent before the observation sessions to meet the ATCO observers, perform the last logistical and equipment checks, and become familiar with the airspace configuration of these positions.

Three days were spent for the observation sessions: two simulation sessions of about one hour each were observed simultaneously on two positions every day with two teams of observers (ATCOs and psychologists). During these sessions approximately six hours of observations were recorded. After each recording session the ATCO and psychologist observers on each position discussed the recorded session and having agreed on the events to be questioned, prepared the interview session. The interviews were then conducted for approximately two hours with the controllers observed.

The controllers involved were both voluntary and experienced. They were all familiar with the simulation environment as well as the sectors which they were working on. Only minor changes to the usual configurations of the sectors were tested at the time, which gave a rather ‘stable’ simulation platform.

3.1.1 Airspace Sectorisation Methods

The reasons for the refinement of the methods were to enhance the quality of the observations and the quality of the interviews, in order to collect events, contextual information, information about what happened in the mind of the observed ATCO as well as information about the actual or potential consequences of observed events with regards to safety. This was achieved in three ways, during three phases, which are presented as follows.

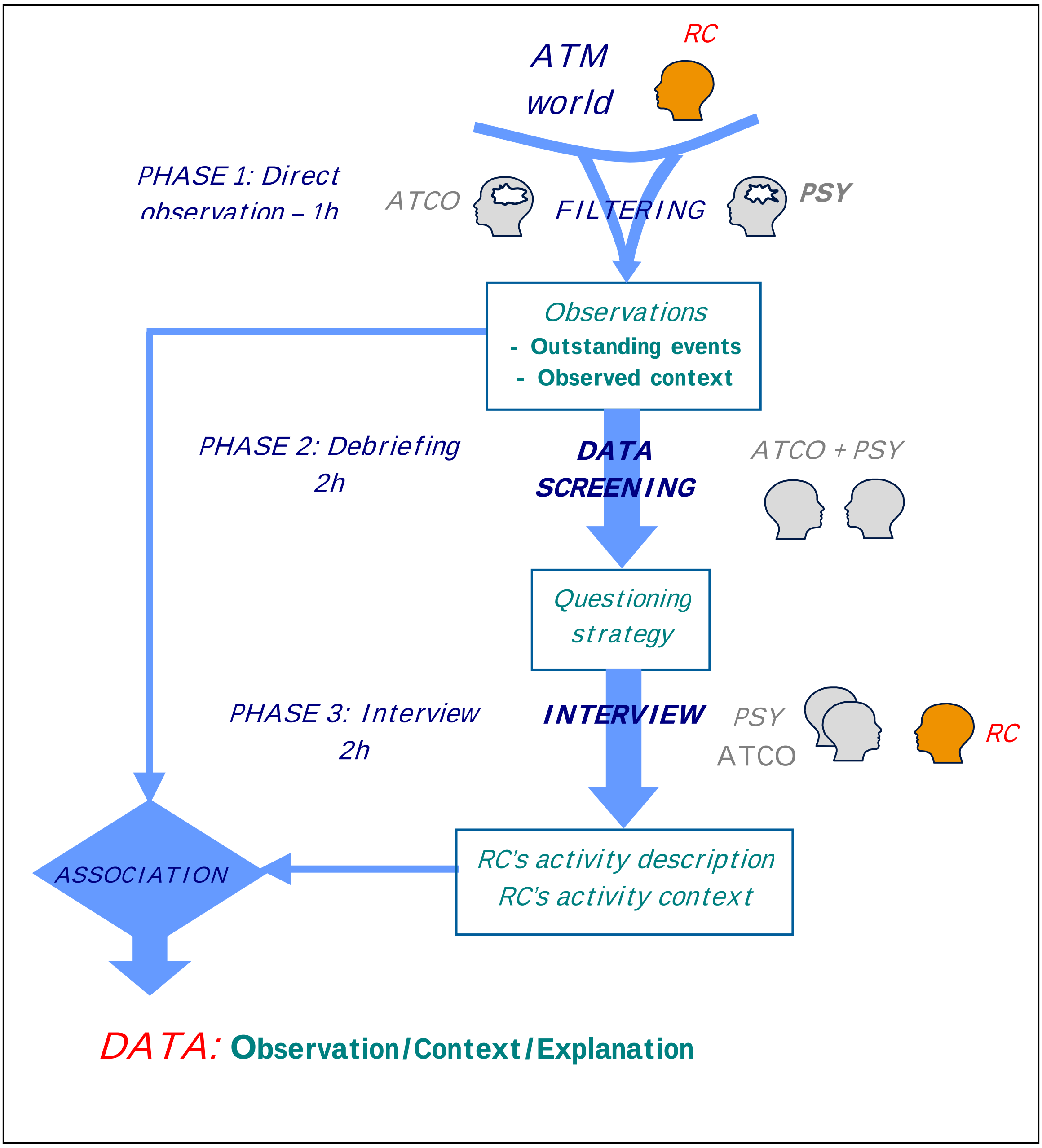

Figure 4: The three phases of the method

Phase 1: Observation

List of Operational observable events. A preliminary list of the operational data observable in ATC was elaborated with the expert ATCO who observed the first simulation exercise. Lists were compiled of actions, events and system states relating to the management of the aircraft from the entry to the exit of the sector.

The resulting lists served as a basis to elaborate the instructions for the observers and the questioning technique of the interviewers. The lists took the observed performance of the controller and not those events which are necessarily error prone.

The full list of these observable events can be found in the ‘Toolkit’, Section 2.2.2 (see EATMP, 2002e).

Observation activities. From the previous simulation exercise it was known that a good combination of personnel for the observations were an ATCO and a psychologist. The Radar Controller (RC) was observed by the ATCO, as the main observer, whilst both were able to monitor the pilot-controller communications.

Each observation lasted for approximately one hour. The observation setting is presented schematically in Figure 5.

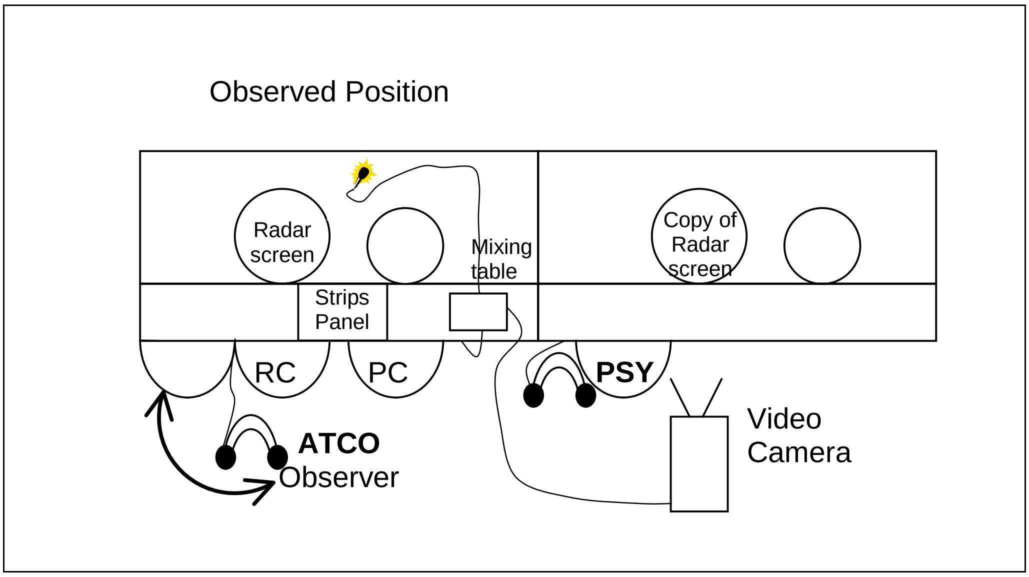

Figure 5: The observation setting

The ATCO observer watched and noted the following issues:

- every action, event or state of the airspace that seemed notable or outstanding, such as:
  - deviations regarding what could be expected from the situation,
  - errors or violations,
  - actions which seemed different to expectation,
  - activities which were not understood,
  - activities which were well achieved;

- every subjective observation on either a tactical or strategic level implemented by the ATCO, with regards to safety.

Both observers took notes of as many observable events as possible: actions, events happening or changing states of the system that were 'outstanding' with regards to their mental model of safe/unsafe professional practices, professional rules and standards. The observers also collected flight progress strips associated with each 'outstanding event'.

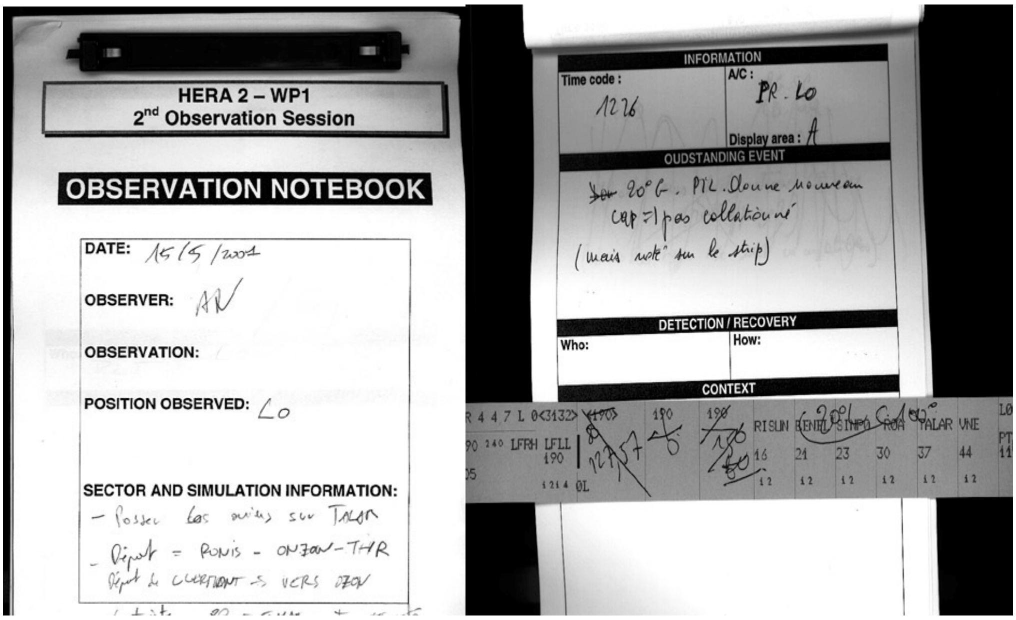

Figure 6: The observation notebook and strips

Both video recording of the radar screen (in the absence of an automatic downloading function) and audio recordings of the radiotelephony and radio were also collected as part of the observation material.

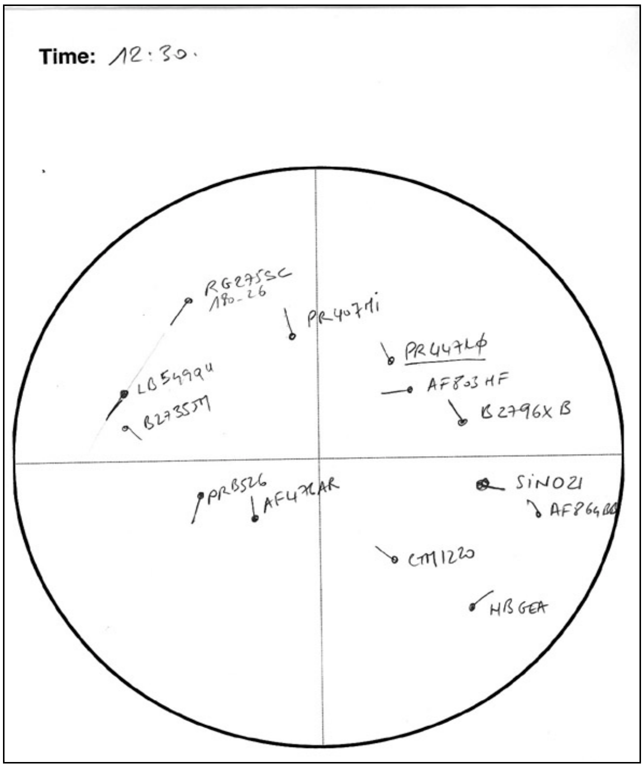

Figure 7: The radar screen recording

The observation notebooks and recording description forms can be found in the ‘Toolkit’, Sections 2.2.5 and 2.2.6 (see EATMP, 2002e).

Phase 2: Debriefing

The debriefing was undertaken in a separate area from the operations room, with the following set up.

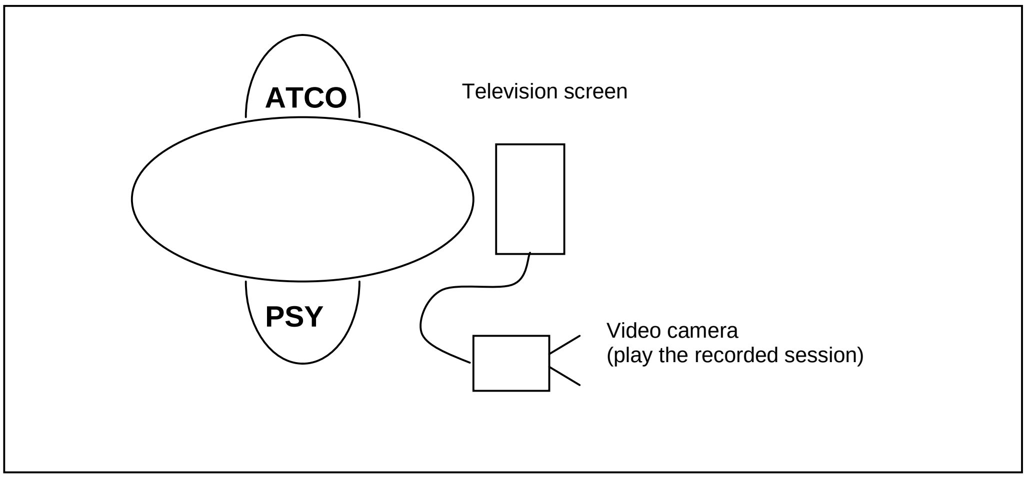

Figure 8: The debriefing setting

The debriefing took place immediately after the observation stage. For each hour of observational recording the debriefing took approximately two hours.

During these sessions, the ATCO and the psychologist reviewed together all the observations made, using both observation notebooks, the collected flight progress strips and recorded video from the radar screen with all RC-PC-pilots' communications. They then discussed in detail all observations, reached agreement on the 'outstanding events' and assigned them identification numbers. They then elaborated the interview questions to be used in the next phase.

This activity resulted in a structured list of observations with associated questions. The questions prepared in the pre-interview notebook were asked to help the observed ATCO describe their activity in an open way.

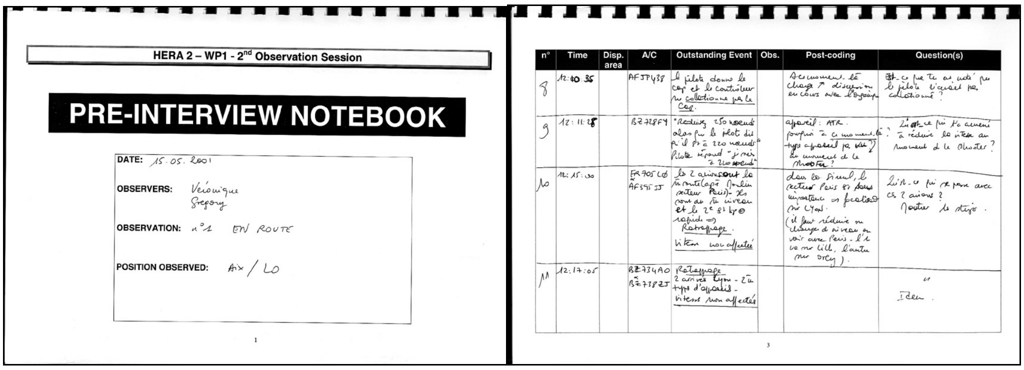

Figure 9: The pre-interview notebook

Further information regarding the questions and the pre-interview notebook can be found in the 'Toolkit', Section 2.3 (see EATMP, 2002e).

Phase 3: Interviews

The interviews took place in the same room as the debriefing session.

For each hour of observation the interview lasted between one hour and one hour and a half. An audiotape recorder was used in these sessions, with the approval of the ATCO. The interviewee was formally asked to agree to the interview and the format of the interview was then explained in detail. All interviewees understood they could withdraw from the process at any time. Although the psychologist led the questioning, the ATCO observer also supported the questions and elaborated where possible with any technical issues.

The effectiveness of the auto-confrontation interviews relied on two variables; firstly, good interview preparation with a pre-analysis of the video recordings and secondly a systematic and thorough questioning of the observations made.

The following issues were considered in the interview process:

- establishment of a good atmosphere for the interview/discussion;
- the restriction within the interview to *what* actually happened in the simulations without questioning *why*;
- guiding and monitoring the interview for elaboration in difficult responses or when non-verbal behaviour was used.

Because of these issues a prescribed interview notebook was used during this phase.

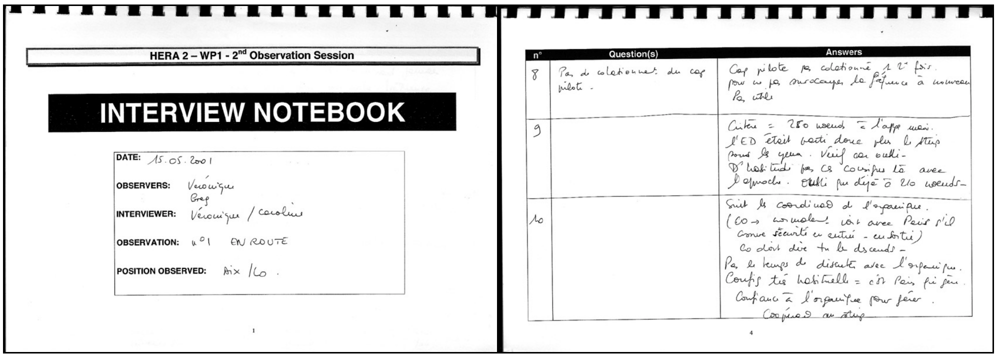

Figure 10: The interview notebook

Further information regarding the methods and the notebook can be found in the 'Toolkit', Section 2.4 (see EATMP, 2002e).

Risk assessment

In order to try and assess qualitatively the degree of risk-taking and situation control by the observed ATCO as well as the way safety has been managed, risk assessment questionnaires were prepared both for the ATCO observer and for the observed ATCO:

- in the course of the interview, the ATCO observer filled in a risk assessment form for each observation commented and a global one at the end of the interview;
- the observed ATCO filled in a different risk assessment form at the end of the interview.

Both forms were compared in order to have a better understanding of the extent to which risk had been taken and managed, hence the extent to which safety had been compromised.

The risk assessment forms can be found in the 'Toolkit', Section 2.4.3 (see EATMP, 2002e).

3.2 Airspace Sectorisation Results

3.2.1 Data summary

A total of 101 observations were gathered after the interviews, in contrast to 91 which had been noted before the interviews.

Table 4: Summary of the data

Simulation sessions	Total observations before interview	Total observations after the interview
En-Route – S1	13	13
Approach – S1	22	26
En-Route – S2	14	18
Approach – S2	19	19
En-Route – S3	9	9
Approach – S3	14	16
Total	**91**	**101**

Clearly, the debriefing among the observers and the interviews enriched the direct observations made.

The full data tables of the six observation sessions are presented in the Appendices.

3.2.2 Qualitative analysis: three main categories of outstanding events

When trying to qualify the types of observations made, it was found that errors and violations were not the only outstanding events, and that all observations fell in three exclusive categories which have been classified as:

- CAs: Correct Actions,
- PAs: Performance Adjustments,
- PDs: Performance Deviations or Errors.

Figure 11 summarises these categories and sub-categories.

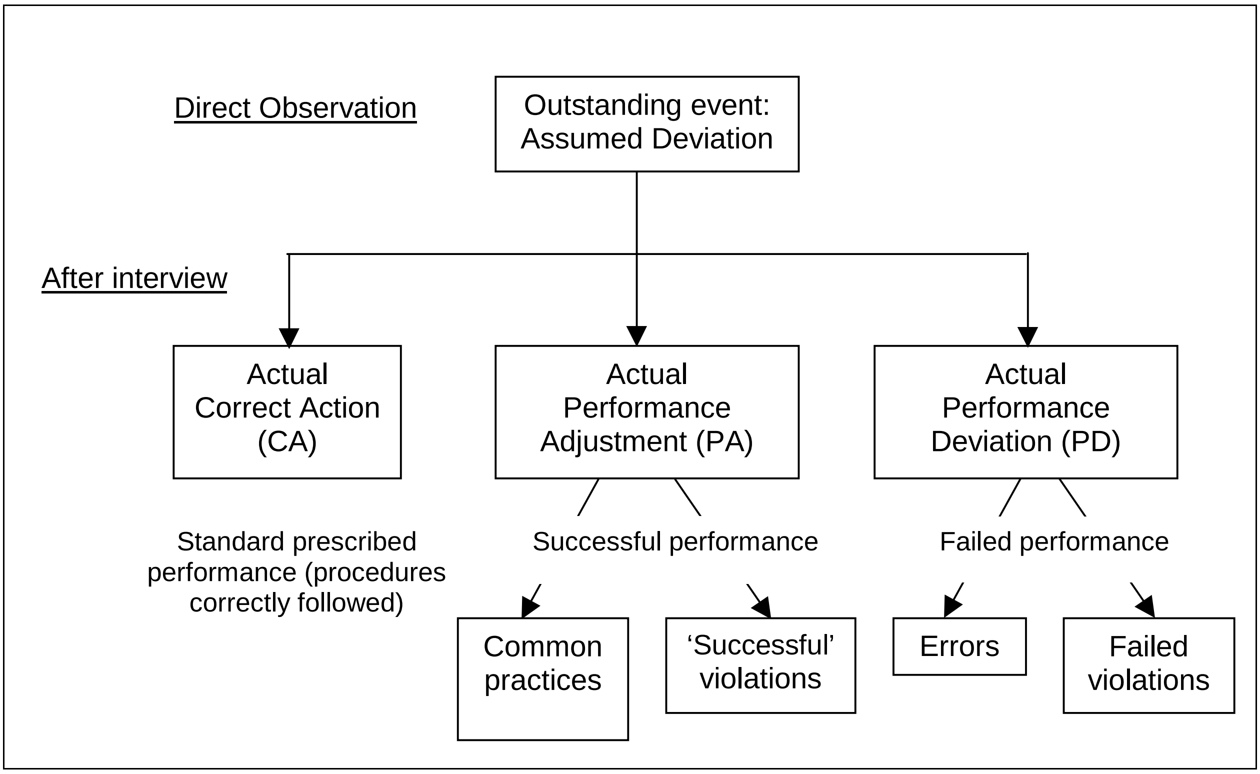

Figure 11: Observation categories

Correct Action (coded CA)

The action performed by the controller proves to be correct as required by the situation and/or by procedures (normal/standard performance). The observer has either misunderstood the situation or was not aware of the procedure to be applied.

Example 1

- Noted by the observer (with regards to the flight strip): "A/C coordinated at FL230 and transferred at FL190."
- Interview: "I cannot give the A/C FL230 because my sector is limited to FL195. Conflicts were solved for this aircraft, so I could transfer it at FL190. I trust the PC has coordinated with the other sector because he has written it on the strip. I followed the standard procedure: clear the A/C at the highest level in my sector."

In this case procedures have been adequately followed, but risk may still be present in the event of inadequate or uncertain procedures, or absence of a procedure.

Performance Adjustment (coded PA)

In this situation the ATCO acts more or less at the margins of what is strictly required by the procedures. This includes all the common accepted and personal practices that usually reach a successful performance. Among PAs also lie clear violations that need to be separated from the common accepted and professionally safe practices. Performance Adjustments are goal-oriented (workload management, strategy, task allocation, etc.) and may be risky or not risky, depending on the situation.

<u>Example 2: Common/preferred practice PA</u>

- Assumed/Noted by the observer: "Aircraft F-MP is given a heading back to its route late after the conflict resolution, compared to aircraft BZ-JM that is headed back immediately."
- Interview: "I could have given the heading to the F-MP immediately but I preferred waiting 2 minutes to group the two instructions (heading and transfer) in one to save time and avoid over-occupying the frequency (there was a lot of traffic). Moreover, it was not dangerous and the heading was not problematic for the F-MP regarding its route."

This performance adjustment was aimed at 'saving resources' and managing the high workload. It was not a risky practice.

<u>Example 3: Violation PA</u>

- Assumed/Noted by the observer: "Catch up situation between two aircraft: absence of speed check when one aircraft was transferred." The procedure states: "Assign a speed to the first aircraft and assign a slower speed to the second one."
- Interview: "The two aircraft come from the same level, they are the same types of aircraft, hence they have the same performance. They have the same wind. For me, there is no problem, they've been under control since the integration of their strips. If I ask for the speed, I loose a lot of time on the frequency. (the traffic was high and workload also high) I had left aside all that was happening elsewhere."

This was a PA that can be considered a routine violation, work strategy to save resources and manage workload. Risk was managed, under control.

<u>Example 4: Risky PA</u>

- Assumed/Noted by the observer: "Conflict between two aircraft: one is going to catch up the other and they are at the same flight level. No instruction is given to manage the conflict (speed allocation)."
- Interview: "I had seen the conflict. But it's the task of the PC to coordinate with the next sector to make sure they accepted to take the A/C like that. There was a lot of traffic so I didn't have time to talk to the PC. The next sector usually manages this kind of situation (the traffic was high and workload also high)."

This observation can be considered a performance adjustment, because the controller was aware of the conflict and was monitoring it. The controller let the PC make a coordination with the next sector. The situation was clearly risky, in the absence of any communication between the two controllers.

Performance Deviation or Error (coded PD)

In this situation the controller acts in a similar way to the performance adjustment but the outcome is actually or potentially different from the intentions or expectations (failed performance). These are classed as errors (unintentional actions or intentions recognised as inappropriate) and the rest of the violations (failed violations that did not reach their goals). Actual Performance Deviations may be risky or not risky, depending on the situation.

Example 5

- Assumed/Noted by the observer: "Aircraft transferred to the feeder controller too early."
- Interview: "The transfer was not very good. It would have been better for me to wait 20 seconds more and pass the cross-point before transferring. This would have avoided the feeder controller wondering whether the conflict was already solved or not. This overloads them and forces them to accept what I thought was fine."

This was an error (action recognised as inappropriate by the controller). The controller took the risk of overloading the feeder controller, hence the situation was risky.

Example 6

- Assumed/Noted by the observer: "The controller gives an instruction to reduce speed to 250 Knots, but the pilot has already announced that he was at 220 Knots."
- Interview: "I had forgotten he was already at 220 Knots. When I transferred it, I remembered I had been given the instruction to deliver the aircraft to the approach controller at a speed of 250 Knots maximum, which was an unusual configuration for me. So, I thought I should check the speed before transferring. I didn't have the strip under my eyes anymore to check."

This was an error. The controller had forgotten the aircraft speed. It was a preventive measure to clear a doubt for safety and teamwork purposes. The situation was not risky.

3.2.3 Quantitative analyses

The summary table of all Correct Action, Performance Adjustment, and Performance Deviation or Error categories is presented in Table 5.

Table 5: Detail of Correct Actions (CAs), Performance Adjustments (PAs) and Performance Deviations or Errors (PDs)

Simulation sessions	CAs	PAs	PDs	Total observations
1 – En-Route-S1	2	7	4	13
2 – Approach-S1	3	20	3	26
3 – En-Route-S2	3	13	2	18
4 – Approach-S2	2	12	5	19
5 – En-Route-S3	2	7	0	9
6 – Approach-S3	3	9	4	16
Total	**15**	**68**	**18**	**101**
Percentage	*14.8%*	*67.3%*	*17.8%*	*100%*

67% of all observations fell into the Performance Adjustment category, which represents the majority of controller behaviour and practice. Almost 18% of the assumed deviations are actual Performance Deviations or Errors, and 15% are standard or Correct Actions.

Errors and violations

The errors and violations in the Performance Adjustment and Performance Deviation or Error categories can be seen in Table 6.

Table 6: Error and Violation categories

Simulation sessions	PAs		PDs	
	Common practices	**Violations**	**Violations**	**Errors**
1 – En-Route-S1	3	4	0	4
2 – Approach-S1	19	1	0	3
3 – En-Route-S2	12	1	0	2
4 – Approach-S2	11	1	1	4
5 – En-Route-S3	5	2	0	0
6 – Approach-S3	9	0	0	4
Total	**59**	**9**	**1**	**17**
Total violations		**10**		
Percentage	*58.4%*	*9.9%*		*16.8%*

There are a total of ten violations (nine PAs + one PD) and seventeen errors (PD), that represent about 27% of all the observations made.

Considering the total observation time was approximately six hours, the observed error rate was 2.83, that is between two and three errors committed in an hour. This result is complimentary to the classical error rate of experts in other working environments. The violation rate is also quite similar to other environments, that is between one and two violations committed every hour.

3.2.4 Risk assessment

The two-fold risk assessment method that was used with the risk assessment forms described in the observation method was implemented during the interviews. The results of these assessments are detailed in the Appendices.

The following tables summarise the risk analyses of the observations, in terms of Correct Action (CA), Performance Adjustment (PA) and Performance Deviation or Error (PD) categories, and errors and violations.

Table 7: Risk assessment in Correct Actions, Performance Adjustments and Performance Deviations or Errors

Simulation sessions	**CAs**		**PAs**		**PDs**	
	No Risk	**Risk**	**No Risk**	**Risk**	**No Risk**	**Risk**
1 – En-Route-S1	2	0	3	4	3	1
2 – Approach-S1	3	0	15	5	2	1
3 – En-Route-S2	3	0	11	2	0	2
4 – Approach-S2	2	0	11	1	1	4
5 – En-Route-S3	2	0	5	2	0	0
6 – Approach-S3	2	1	4	5	2	2
Total	**14**	**1**	**49**	**19**	**8**	**10**
Total	*15*		*68*		*18*	

Overall 28% of the Performance Adjustments are risky, versus 55% of the Performance Deviations or Errors and 0.06% of the Correct Actions.

Table 8: Risk assessment in Error and Violation categories

	No Risk	**Risk**	**Total**
Errors	8	9	**17**
Violations	2	8	**10**
Total	**10**	**17**	**27**

In total, 80% of the observed violations are risky versus 53% of the observed errors.

3.2.5 HERA analyses of the errors and violations

The full table of the ten violations (PA and PD violations) and seventeen errors (PDs) that came out of the observations is presented in the Appendices. From these observations one error[2] was considered unsuitable to classify with HERA and therefore the following tables illustrate the analyses of sixteen errors and ten violations.

Error Types (ETs) and Contextual Conditions (CCs)

Table 9: The error and violation types

Error/violation types	Number
Action timing	
Action too early	2
Action too late	2
Action selection	
Omission	1
Action in wrong direction	1
Wrong action on right object	3
Right action on wrong object	1
Unnecessary act	1
Information	
Unclear information sent	2
Incomplete information sent	1
Incorrect information sent	2
Violation	
Routine violation	6
General violation	4
Total	**26**

The errors recorded were found in all of the HERA categorisations, the largest being found in the action selection category (seven). Among the ten violations six were routine violations (60%) and four were general violations (40%).

[2] The error that was not analysed with the HERA Technique is referred to as E15 (AP-S3 / 91) in Appendix 2. The explanations are provided at the beginning of the table presenting the results of the HERA analyses of all the remaining 26 errors and violations (see Section 2.3).

The main categories of Contextual Conditions were found in the following HERA classifications:

Table 10: The Contextual Conditions

Contextual Conditions	Number
Environment - simulation - general	16 1
Traffic and airspace	13
Team factors	4
Pilot-controller communication	3
Documentation and procedures	2
Total	**39**

The strong effect of the simulation context appears quite clearly. Sixteen of the 39 Contextual Conditions (41%) are related to the simulation itself. Thirteen of the Contextual Conditions (33%) are linked to traffic and airspace specifications, which is precisely what was being tested in this simulation.

Error Details, Error Mechanisms and Information Processing levels

The Error Detail and Error Mechanism categories are presented as follows:

Table 11: The Error Details and Error Mechanisms

Error Details and Error Mechanisms	Number
Perception and vigilance	
No detection (visual)	1
Working memory	
Forget planned action	1
Inaccurate recall of temporary information	2
Long-term memory	
No recall of temporary information	1
Planning and decision-making	
Misprojection of aircraft	2
Incorrect decision or plan	4
Late decision or plan	1
Response execution	
Selection error	1
Incorrect information transmitted	2
Unclear information transmitted	1

The main Error Details and Mechanisms appear to be related to planning and decision-making (seven) and response execution (four).

The Information Processing levels are presented as follows:

Table 12: The Information Processing levels

Information Processing levels	Number
Perception and vigilance	
Monitoring failure	1
Working memory	
Preoccupation	3
Similarity of information	1
Planning and decision-making	
Lack of knowledge	1
Failure to consider side effects	3
Failure to integrate information	1
Failure to recognise risk	2
Incorrect priority of tasks	1
Response execution	
Problem of habit	1
Unclear speech	1
Spatial confusion	1
Slip of the tongue	2

Two errors were associated with more than one Information Processing level, but the main errors in this categorisation were associated with preoccupation (three) and failure to consider side effects (three).

Analyses of the violations

The following categories have been assessed regarding the goals of the observed violations.

Table 13: Goals of the violations

Goals of the violations	Number
Airspace configuration	1
To limit the use of R/T	1
Workload management	3
Workload management of the adjacent sector	2
Goal unidentified	3

The results indicate there is a tendency to violate the rules for workload management purposes: 50% of violations aim at reducing one's own workload or the workload of the adjacent sector.

No differences between routine and general violation can be noticed regarding their goals - six of the violations were routine violations and four were general violations.

The three violations with no identified goal were representative of the difficulties in this environment to question violation practices.

Error management

Among all the errors observed 50% were detected and recovered, 45% were neither detected nor recovered and one error was detected but not recovered.

3.2.6 Transverse analyses or the errors and violations

Tasks involved in the errors/violations observed

The task categories of the observed errors and violations are presented in Table 14.

Table 14: Task categories of errors and violations

Task	Errors	Violations	Number
Instruction AND clearance	8	5	13
Coordination between sectors	2	3	5
Conflict resolution	2		2
Readback		2	2
Control room communication between sector AND instruction	1		1
HMI input AND functions	1		1
Planning	1		1
Radar monitoring	1		1
Total	**16**	**10**	**26**

50% (thirteen out of 26) of the errors and violations observed involved instruction or clearance delivery by the controller. This is not surprising considering that most of the controller activity consists of communicating with aircraft.

19% (five out of 26) of errors and violations observed involved a coordination between sectors. This could be explained by the simulation bias since in the simulations the space sharing between sectors was sometimes understood differently amongst the controllers.

Information and Equipment involved in the errors and violations observed

The Information and Equipment categories of the observed errors and violations are presented below.

Table 15: Information and Equipment of errors and violations

Information and Equipment	Errors	Violations	Number
Heading	3	2	5
Call sign	2	1	3
Heading AND conflict	3		3
Clearance	1	1	2
Descent		2	2
Flight level AND speed		2	2
Transfer	1	1	2
ATS equipment AND primary radar / touch	1		1
Clearance AND other-language	1		1
Clearance AND transfer	1		1
Conflict	1		1
Coordination AND transfer	1		1
Descent AND flight level AND holding	1		1
Flight level		1	1
Total	**16**	**10**	**26**

The variability of the Information and Equipment that are the topics of the observed errors and violations is representative of the diversity of the information and equipment usually used by controllers.

4. CONCLUSIONS

This report has presented the methods proposed to observe controller errors and violations in real-time simulated environments, as well as the analyses, with the HERA Technique, of the data gathered in the two simulations.

Several predicted problems were realised during the simulation exercises.

Firstly, there had to be a precise definition of error and violation which was understood by all observers.

Secondly, the method required not only an expert in the ATC environment, to understand the thinking behind many of the controller activities, but also the support of a psychologist to interpret many of the actions seen from a human information processing standpoint.

Thirdly, the observation methodology had to be thorough in order to elicit the thinking behind the observed erroneous or outstanding events. This method had to include the questioning of the controllers own thinking with respect to their error management strategies.

Lastly, the method had to take into account the sensitivities of all the professionals involved and present clear and precise goals in the observation environment.

The main results from the simulation observations illustrated the diversity of errors made, and indicated that the majority of Performance Deviations or Errors were found in the planning and decision-making category. This reflects the work undertaken in the HERA 1 Project which found a similar trend in terms of incident investigation. More importantly, the observation and interview activities explored the reasons why controllers made decisions about some of the events noted. It was realised that as expert decision-makers, within the ATC environment, they were able to judge the displayed information and action a response which was not obvious to the observers present. Once questioned the controllers were able to explain their chosen actions, or inaction, and this behaviour was labelled Performance Adjustment. Information was also collected with regard to the degree of risk taken during the simulations.

The final method proved to be efficient in terms of data gathering, since only a few of the analysable events lacked data. Sufficient data was also gathered with the observation methods to apply the HERA Technique to the errors and violations observed. The method also supported the data collection of information about safety management and performance adjustments. Valuable information about how air traffic controllers actually work, how they ‘play’ with the system margins, take risks and manage safety was also gathered.

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ABBREVIATIONS AND ACRONYMS

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

A/C	Aircraft
ATC	Air Traffic Control
ATCO	Air Traffic Controller / Air Traffic Control Officer *(US/UK)*
ATM	Air Traffic Management
CA	Correct Action
CAA	Civil Aviation Authority / Administration
CCs	Contextual Conditions
DIS	Director(ate) Infrastructure, ATC Systems & Support *(EUROCONTROL Headquarters, SDE)*
DIS/HUM	See ‘HUM (Unit)’
EATCHIP	European Air Traffic Control Harmonisation and Integration Programme *(now EATMP)*
EATMP	European Air Traffic Management Programme *(formerly EATCHIP)*
ECAC	European Civil Aviation Conference
ED	Error Detail
EM	Error Mechanism
ET	Error Type
FAA	Federal Aviation Administration *(US)*
FL	Flight Level
FR	Free Routing
FRAP	Free Route Airspace Project
HERA (Project)	Human Error in ATM (Project)
HERA 1	HERA Project Phase 1
HERA 2	HERA Project Phase 2
HFSG	Human Factors Sub-Group *(EATCHIP/EATMP, HUM, HRT)*

HMI	Human-Machine Interface
HRS	Human Resources Programme *(EATMP, HUM)*
HRT	Human Resources Team *(EATCHIP/EATMP, HUM)*
HSP	Human Factors Sub-Programme *(EATMP, HUM, HRS)*
HUM	Human Resources (Domain) *(EATCHIP/EATMP)*
HUM (Unit)	Human Factors and Manpower Unit *(EUROCONTROL Headquarters, SDE, DIS; also known as 'DIS/HUM')*
IANS	Institute of Air Navigation Services *(EUROCONTROL, Luxembourg)*
IP	Information Processing level
PA	Performance Adjustment
PC	Planning Controller
PD	Performance Deviation or Error
RC	Radar Controller
REP	Report *(EATCHIP/EATMP)*
SDE	Senior Director, Principal EATMP Directorate *or, in short,* Senior Director(ate) EATMP *(EUROCONTROL Headquarters)*
STCA	Short-Term Conflict Alert
WP	Work Package *(EATCHIP/EATMP)*

CONTRIBUTORS

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APPENDIX 1: DATA FROM THE FIRST SIMULATION EXERCISE

The following table presents the data gathered by the Air Traffic Controller (ATCO) and the psychologist (PSY) observers during three real-time observation sessions at the simulation in the EUROCONTROL's Experimental Centre (EEC), Brétigny, France (Free Route Airspace Project [FRAP]).

The columns of the tables are as follows:

- N°: Observation number.
- Simulation number: S1 (Simulation n°1: Wednesday 6 September 2000), S2 (Simulation n°2: Thursday 7 September 2000) or S3 (Simulation n°3: Thursday 14 September 2000).
- Questioned during the interview:
- Observer: ATCO and/or PSY.
- Raw observations: Free text of the direct on-line observation made by the ATCO and/or PSY.
- Detection: If yes, by whom: RC (Radar Controller, i.e. the controller observed), PC (Planning Controller), Pilot, System (e.g. the STCA), HMI (Human-Machine Interface), or Adjacent Sector.
- Recovery: If yes, by whom.
- Prevention: If yes, by whom.

1.1 Summary Table of the Raw Observations

N°	Simulation number	Questioned during the interview	Observer	Raw observations	Detection	Recovery	Prevention
1	S1		ATCO	Callsign error	RC	RC	
2	S1	✓	ATCO & PSY	Transfer too soon?			
3	S1		ATCO	Callsign error by the pilot	RC	RC	
4	S1		ATCO	Input error / HMI	HMI	RC	
5	S1	✓	ATCO	STCA (HMI problem)		RC	
6	S1		ATCO	Late input / HMI		RC	
7	S1		ATCO	Assigned route unknown to pilot			
8	S1		ATCO	Input error (JKK101)	RC	RC	
9	S1	✓	ATCO	Transfer too late	PC	RC	
10	S1		ATCO	Input error	RC	RC	
11	S1		ATCO	Search for calling aircraft			
12	S1		ATCO	Slowness of the system	RC+PC		
13	S1		ATCO	Who’s calling?		RC	
14	S1		ATCO	Late call by pilot	PC		
15	S1		ATCO	Late input (assigned heading)		RC	
16	S1		ATCO	Late input (assigned heading)		RC	
17	S1	✓	ATCO & PSY	STCA (unjustified)			
18	S1	✓	ATCO	Late transfer (BMA-AB)			
19	S1		ATCO	Input error (AFR)	RC	RC	
20	S1	✓	ATCO	Acknowledgement error / Pilot	RC	RC	
21	S1		ATCO	Transfer frequency error	Pilot	RC	
22	S1	✓	ATCO	Wrong exit level (AFR2012)	RC		
23	S1	✓	ATCO	Wrong next sector (AFR2012)	PC		
24	S1	✓	ATCO & PSY	Transfer to wrong sector (AFR2012)		RC	
25	S1		ATCO	Unidentified calling aircraft (DLH)			
26	S1		ATCO	Transfer to wrong sector (USA95) (HMI problem)			
27	S1		ATCO	Callsign error between PC & RC	RC	RC	
28	S1	✓	ATCO	Input error / HMI			
29	S1	✓	ATCO	Unidentified caller			

N°	Simulation number	Questioned during the interview	Observer	Raw observations	Detection	Recovery	Prevention
30	S1	✓	ATCO	Unidentified caller			
31	S1	✓	ATCO	Conflicting trajectories: stop climb!	Adj. Sector	RC	
32	S1		ATCO	Wrong window displayed (AFR)			
33	S1		ATCO	Change in strategy	?	?	
34	S1	✓	ATCO	Late transfer			
35	S1	✓	ATCO	Late transfer (BAW23DM)?			
36	S1		ATCO	Transfer without cancelling assigned heading (AHR502)			
37	S1		ATCO	CSA call with no reply			
38	S1		ATCO & PSY	Conflicting trajectories F-TB / ADRIA STCA	HMI	RC	
39	S1		ATCO	Late descent (AFR 1763)			
40	S1		ATCO	Assigned heading too long late FREE (CYPR)	RC	RC	
41	S1		ATCO	Transfer before coordination			
42	S1		PSY	Multiple verifications of plane data			RC
43	S1		PSY	Input error (missed)	RC	RC	
44	S1		PSY	Unable to identify calling plane	RC	RC	
45	S1		PSY	Misunderstanding with a pilot	RC	RC	
46	S1		PSY	HMI input error			
47	S1		PSY	Assigned heading late input	RC		
48	S1		PSY	Error of communication	RC	Pilot	
49	S1		PSY	Consultation aircraft data*			
50	S1		PSY	Pilot acknowledgement by pilot	RC	Pilot	
51	S1		PSY	Aircraft spacing	?	?	
52	S1		PSY	Aircraft spacing	?	?	
53	S2		ATCO	Readback error	RC	RC	
54	S2		ATCO	Did not identify the calling pilot		PC	
55	S2		ATCO	Pilot readback error			
56	S2		ATCO	Callsign confusion + correction	RC	RC	
57	S2		ATCO	No pilot reply	RC	RC	
58	S2	✓	ATCO	Kept the green trajectory on display			RC

N°	Simulation number	Questioned during the interview	Observer	Raw observations	Detection	Recovery	Prevention
59	S2		ATCO	Move the tag			RC
60	S2	✓	ATCO & PSY	Uncertainty on military activity	RC	PC	
61	S2		ATCO	Input HMI before clearance delivered			RC
62	S2		ATCO	Did not identify the calling pilot	PC	RC	
63	S2	✓	ATCO & PSY	Green trajectory on display			RC
64	S2		ATCO	Late identification / DLH4627		RC	
65	S2	✓	ATCO	No answer to a call	PC (Assume)		
66	S2	✓	ATCO	Forget to begin descent to FL270 (BAW)			
67	S2		ATCO	Pilot readback error	RC	RC	
68	S2		ATCO	Clearance + revision (SAS 582)	PC	RC	
69	S2		ATCO	Bad selection within the HMI menu		RC	
70	S2		ATCO	Non standard flight level (SAB779)	PC	RC	
71	S2		ATCO	Controller-pilot misunderstanding (question = authorisation)			
72	S2		ATCO	Callsign mistake (BMA instead of BAL)	PC	RC	
73	S2		ATCO	No answer to SAS504 calling			
74	S2		ATCO	Stabilise 2000ft under its Clearance			
75	S2		ATCO	EIN657 left at FL280 instead of FL 340	PC	RC	
76	S2		ATCO	Callsign error	Pilot	RC	
77	S2		PSY	Moving tags so as to keep it readable			RC
78	S2	✓	PSY	«a problem here»: detection of a potential conflict	RC		
79	S2		PSY	Cannot see the calling aircraft (asks the PC to look for something?)		PC	
80	S2	✓	PSY	Marking an aircraft (HMI function) after a discussion with PC			RC
81	S2		PSY	Pilot hearback (pilot)			
82	S2		PSY	Bad use of the mouse (wrong selection within a menu)	RC	RC	
83	S2	✓	PSY	No detection of a pilot error			
84	S2	✓	PSY	Problem with an aircraft: request for details at debriefing	?	?	?
85	S2		PSY	Bad use of the mouse (X2)	RC	RC	

N°	Simulation number	Questioned during the interview	Observer	Raw observations	Detection	Recovery	Prevention
86	S2		PSY	Communication error (hurry)	RC	RC	
87	S2		PSY	Reading error, communication (slip on the tongue) or attention (pilot)	Pilot	RC	
88	S3		ATCO	Input error / HMI	RC	RC	
89	S3		ATCO	Change heading (FAF7401) So as to avoid VKL on departure			RC
90	S3		ATCO	Request for climb (BAW7)	PC		PC
91	S3		ATCO	Two aircraft fly through northern military zone with no coordination	PC		
92	S3		ATCO	Traffic calling on wrong frequency (Tiger)	RC	PC+RC	
93	S3		ATCO	Traffic cutting into military zone (R8) with no coordination (DLH)	PC		
94	S3	✓	ATCO & PSY	Conflicting trajectories between an aircraft in descent and a civilian traffic in transit (HLF)	PC	RC (expedite)	
95	S3		ATCO	Conflict detection (entering the sector)	PC	PC	
96	S3		ATCO	Callsign error (crossed tags)	RC	RC	
97	S3		ATCO	Clearance delivered to the wrong aircraft	Pilot	RC	
98	S3		ATCO	No «ASSUM» input when the F16 come back from the northern zone.			
99	S3		PSY	Zoom function: building or checking SA			RC
100	S3		PSY	Beginning of the recording			
101	S3	✓	PSY	Green trajectory line on direct track (= clearance for direct route?)			
102	S3		PSY	Getting the working environment set (hard and soft)			RC
103	S3		PSY	Marking a plane			RC
104	S3		PSY	A potential conflict detected among several flights within his sector / under his responsibility	RC		
105	S3	✓	PSY	Marking a plane (this plane kept its mark even after solving the problem / did he forget to take it off?)			
106	S3		PSY	Bad use of the mouse (missed input)	RC	RC	
107	S3		PSY	Green trajectory lines on display			RC

N°	Simulation number	Questioned during the interview	Observer	Raw observations	Detection	Recovery	Prevention
108	S3		PSY	Potential conflict detection (not associated to an error) involving an expected flight not yet on the screen	RC		
109	S3		PSY	A series of military flights is transferred, except for the last one (just after an interruption / lack of attention or a miss?)	RC	RC	
110	S3		PSY	Bad hearback (busy talking with PC: error or violation?)			
111	S3		PSY	Green trajectory lines put on display (X2) just as he says «olalala!" (conflict detection?)	RC		
112	S3		PSY	Communication error with CO	RC	RC	
113	S3		PSY	Display of the green trajectory line for a marked aircraft (checking or planning?)			RC
114	S3		PSY	Getting the working environment set (different menus, windows and screen settings)			RC
115	S3		PSY	Communication error with pilot	RC	RC	
116	S3		PSY	Other controller error on the aircraft tag (altitude information)	RC		
117	S3		PSY	Coordination problem with the MW sector?			
118	S3	✓	PSY	Marking a plane: Potential conflict detection			
119	S3		PSY	An aircraft is verbally identified with no HMI input (did he forget?)			
120	S3		PSY	A clearance to the wrong aircraft (crossed tags)	RC	Pilot	
121	S3		PSY	Pilot readback error and controller hearback error	Pilot	Pilot	

1.2 Results of the Interviews

The results of the auto-confrontations/interviews are presented below. The observations questioned are referred to with their identification number.

Observations have been questioned alone or in groups due to their similarities. Sometimes, however, they have been grouped after the interview on the basis of the information provided. The results are presented in the following way: Group [5, 17, 38] provides the information collected during the interview for the three observations 5, 17 and 38.

1.2.1 Simulation N°1

N° 2: Anticipated transfer of planes corresponds to a strategy of prevention: this permits early transfer of planes which then no longer require surveillance (resource management).

Group [N° 5, n°17 and n°38]: Even in the case of a STCA, the controller may decide to do nothing because "these alarms are not always relevant".

Group [N° 9, n°18, n°34 and n°35]: Certain late transfers are the result of a conflict detected a little late: as the controller does not want to transfer an unseparated plane, he wants to solve the conflict first and so delays transfer. In addition, when the workload is heavy (e.g. resolution of a conflict) the other planes may be momentarily "forgotten". These situations are typical of working "near the limits".

Group [N° 22 and n°23]: Detection of an error of attention - the level of a plane had been changed but the implications were not foreseen (potential conflict with another plane). One could invoke a lack of anticipation on the part of the controller (failure to take into account medium/long term). This failure of anticipation could show up in connection with the beginnings of a strategy of recovery of the error (partial recovery as it was finally ineffective) or because of a faulty representation when the decision was made.

N°24: Transfer of a plane without permission. The explanation given by the controller points to a strong expectation (bias towards confirmation). Transfers are reduced by proposals. In 90% of cases the proposals are accepted by the neighbouring sector. Consequently, one expects that this will always follow. When this does not happen, the controller is surprised, thinking that the plane has been transferred.

N° 28: Attention error: light traffic - manifestation: input error.

Group [N°29 and n°30]: Difficulty in identification of the caller.

N°31: Undetected conflict.

Notes

- Certain manipulations which could have been interpreted as missed actions with the HMI were simply 'play with the mouse' to pass time when nothing happened.

- The controller justified many errors by reasons of habit acquired in relation to real work, poor knowledge of the HMI and 'lack of logic' of certain procedures or configurations.

1.2.2 Simulation N°2

<u>Group [N°58 and n°63]</u>: Use of the green trajectory line as a 'reminder'.

<u>N°60</u>: The controller did not answer two consecutive pilot calls: the controller explains that he was busy elsewhere (he was trying to find out if a military zone was active or not) and that that aircraft was not 'important' at that moment. This action cannot be considered an error because it seems to be intentional on the controller's behalf.

<u>Group [N°65 and n°80]</u>: Although the aircraft was marked (prevention) the controller forgets to give the aircraft descent clearance. At this flight level, it was in conflict with another aircraft. The problem is identified by PC and recovered immediately by RC.

<u>N°66</u>: Incoherent information on the aircraft label - it could have several causes amongst which a data input error. During the debriefing the controller could not remember why this happened.

<u>N°78</u>: 'maybe a problem' - the controller detects a potential conflict. One of the planes was not his, he identifies the problem without solving it (partial recovery) by marking the aircraft (HMI function).

<u>N°83</u>: 'error of detection' - by the controller. He did not notice the unexpected change of direction of a plane exiting from a zone. The controller explained that by the fact that the plane was exiting and that it is supposed to be free-route.

<u>N°84</u>: Several interpretations of the facts (1) the controller forgot to input after giving clearance, (2) he repeats the clearance already given but the plane does not seem to ascend, (3) he has previously input 300 without giving clearance to the plane. The controller is unable to choose among these options and cannot understand what has happened.

<u>Notes</u>

- HMI problem: Some of the primary functions are not directly accessible for the controller (long navigation within the various menus). Example: display of different military zones.
- The controller justifies some of his actions by a 'negative learning transfer'.

1.2.3 Simulation N°3

<u>N°94:</u> The controller has not identified the conflict pointed out by the PC that leads to a slightly late recovery (no conflict detection) with the use of 'expedite'.

<u>N°101</u>: The direct routing is intentional so as to simplify the situation.

<u>N°118</u>: It seems to be a bad use of the mouse and nothing to do with a prevention strategy.

<u>Notes</u>

- Some aircraft HMI marks are cancelled when no longer useful - according to the controller, he cancels them systematically as soon as the aircraft is clear of traffic.
- The aircraft marking is associated to a prevention strategy (potential conflict).

The table on the next page presents the summary of the HERA analyses of the 24 observations.

The columns of the tables are as follows:

- N°: Observation number (referring to the numbering in the previous table).
- Simulation number: S1 (Simulation n°1: Wednesday 6 September 2000), S2 (Simulation n°2: Thursday 7 September 2000) or S3 (Simulation n°3: Thursday 14 September 2000).
- ET: Error/Violation Type: Error or violation which was the subject of the occurrence.
- Task(s): Task(s) which was (were) being undertaken at the time of the occurrence.
- ED: Error Detail: Error detail which was the subject of the occurrence.
- EM: Error Mechanism: Error mechanism which was the subject of the occurrence.
- IP: Information Processing level: Information processing level which was the subject of the occurrence.
- CCs: Contextual Conditions: Those conditions in which the controller was working.
- Problems and difficulties encountered: Those problems and difficulties encountered during the HERA analysis.

Regarding the Contextual Conditions (CCs) the simulation created a very particular context, which is described hereafter:

- *Documentation and Procedures: New/Recent changes:* The controllers were not familiar with the procedures because the test of procedures was actually the topic of the simulation;
- Training and Experience: Inadequate experience on position and unfamiliar task in routine operations and novel situation; this set of CCs is referred to as the ‘simulation context’.

1.3 Summary of the HERA Analyses

N°	Simulation number	ETs[3]	Task(s)[3]	EDs[3]	EMs[3]	IPs[3]	CCs[3]	Problems and difficulties encountered
2	S1	Action too early (earlier transfer)	-	-	-	-	FRAP context	Error prevention action
5	S1	STCA	-	-	-	-	FRAP context	Consequences of previous erroneous actions without knowing anything about them
9	S1	Action too late (late transfers)	Unknown	Memory / Planning and decision-making	Prospective memory failure / Late decision or plan	Cannot be determined	FRAP context	Available data not sufficient to answer the questions
17	S1	STCA	-	-	-	-	FRAP context	Consequences of previous erroneous actions without knowing anything about them
18	S1	Action too late (late transfers)	Unknown	Memory / Planning and decision-making	Prospective memory failure / Late decision or plan	Cannot be determined	FRAP context	Available data not sufficient to answer the questions
22	S1	Wrong exit level / Wrong next sector	-	-	-	-	FRAP context	1/ Consequences of an original erroneous action for which we are lacking data 2/ Weakness of the interviews
23	S1	Wrong exit level / Wrong next sector	-	-	-	-	FRAP context	1/ Consequences of an original erroneous action for which we are lacking data 2/ Weakness of the interviews

[3] ETs: Error Types – EDs: Error Details – EMs: Error Mechanisms – IPs: Information Processing levels – CCs: Contextual Conditions.

N°	Simulation number	ETs[3]	Task(s)[3]	EDs[3]	EMs[3]	IPs[3]	CCs[3]	Problems and difficulties encountered
24	S1	Wrong action on right object (transfer to a wrong sector)	Coordination inter-unit	-	-	-	FRAP context	Consequences of an original erroneous action for which we are lacking data
28	S1	Input error	HMI input	Cannot be determined	Cannot be determined	Cannot be determined	FRAP context	Available data not sufficient to answer the questions
29	S1	Omission (unidentified caller)	Readback (request)	Perception and Vigilance	Misidentification; Misread; Visual misperception; No identification; Late identification	Vigilance failure	FRAP context	1/ Lack of data 2/ Inferences 3/ Question ambiguity
30	S1	Omission (unidentified caller)	Readback (request)	Perception and Vigilance	Misidentification; Misread; Visual misperception; No identification; Late identification	Vigilance failure	FRAP context	1/ Lack of data 2/ Inferences 3/ Question ambiguity
31	S1	Omission (undetected potential conflict)	Cannot be determined: (traffic management)	Perception and Vigilance	Cannot be determined	Vigilance failure	FRAP context	1/ Collective error management sequence 2/ Lack of data 3/ Conclusion obvious
34	S1	Action too late (late transfers)	Unknown	Memory / Planning and decision-making	Prospective memory failure / Late decision or plan	Cannot be determined	FRAP context	Available data not sufficient to answer the questions
35	S1	Action too late (late transfers)	Unknown	Memory / Planning and decision-making	Prospective memory failure / Late decision or plan	Cannot be determined	FRAP context	Available data not sufficient to answer the questions
38	S1	STCA	-	-	-	-	FRAP context	This STCA was due to a strategic choice

N°	Simulation number	ETs[3]	Task(s)[3]	EDs[3]	EMs[3]	IPs[3]	CCs[3]	Problems and difficulties encountered
60	S2	Omission OR Violation (no replying to a pilot)	-	-	-	-	FRAP context	1/ Observable differences between ATCO and PSY 2/ Error or violation status not decidable 3/ Lack of data
65	S2	–	-	-	-	-	FRAP context	Weakness of the observations and interviews: no data available + data ambiguities
66	S2	Omission (tag incoherence)	-	-	-	-	FRAP context	Weakness of the observations and interviews: no data available
78	S2	–	-	-	-	-	FRAP context	Detection of a potential conflict / Error prevention action
80	S2	–	-	-	-	-	FRAP context	Weakness of the observations and interviews: no data available + data ambiguities
83	S2	Omission (undetected changes in plane's direction)	Unknown	Perception and Vigilance	No detection (visual)	Not decidable: Perception discrimination failure OR Out of sight bias	FRAP context	Lack of data
84	S2	Problem with an aircraft request	-	-	-	-	-	Method weakness: 1/ Event report too confused 2/ Lack of data 3/ Video not displayable
94	S3	Omission (conflict trajectories)	Unknown	Perception and Vigilance	No detection (visual)	Cannot be determined	FRAP context	Lack of data
118	S3	Input error	HMI input and function: mouse	Response execution	Selection error	Manual variability	FRAP context	Conclusion obvious

APPENDIX 2: DATA FROM THE SECOND SIMULATION EXERCISE

The first table presents the details of one observation, to show how the data gathered were recorded and analysed after the simulation sessions. All the remaining data was analysed in the same way.

The second table presents a short summary of the data gathered during the six simulation sessions observed.

The data includes the raw observations with embedded context, the explanations provided during the interview and the post-qualification in terms of CA/PA/PD (Correct Action / Performance Adjustment / Performance Deviation), Error/Violation and Risky/Non Risky:

The following simulation codes have been used:

1. Simulation day 1 – En-Route: ER-S1.

2. Simulation day 1 – Approach: AP-S1.

3. Simulation day 2 – En-Route: ER-S2.

4. Simulation day 2 – Approach: AP-S2.

5. Simulation day 3 – En-Route: ER-S3.

6. Simulation day 3 – Approach: AP-S3.

The third table presents a summary of the errors and violations analysed with the HERA Technique.

2.1 Example of Detailed Data Recording for One Observation

From the observations, the audiotapes of the interviews and the data of the pre-interview and interview notebooks, the information was merged together into a single table, an example of which is presented as follows.

The first columns of the table record the information gathered from the pre-interview notebook (observation number, time code, concerned A/C(s) and observer, outstanding event and observed context). The questions and answers' columns are filled with the actual questions asked by the psychologist and the actual answers provided by the observed ATCO according to the audio recording of the interview. The last two columns of the table concern the qualification of the observations. The first column qualifies the observation in terms of PA (Performance Adjustment), PD (Performance Deviation) or CA (Correct Action), Error or Violation. Risk is assessed in the last column: Yes (Risky) or No (Non Risky).

N°	Time	A/C	Outstanding Event Observed Context	Question(s)	Answers	PA/PD/CA Error/Violation	Risk
6	12 :10 :00	LBED298 & BZ728FY ATCO observer	No check of the A/C speeds when the LBED298 has been shot. Catch-up situation. Regulation of the 2 A/C on TALAR. The 2 A/C (two ATR43) descend at the same FL on LYON approach. No speed reduction although small radar separation between them. Procedure: the first A/C should be assigned a speed and the second one should be assigned an inferior speed.	In the context of the TALAR regulation: what can you tell me about the speed regulation of these two A/Cs?	Explanations «The two A/C come from the same level, they are of the same type: 2 ATR43, hence, they have the same performances, the same speed, they cannot go beyond 210 Knots in descent. For me, they have been controlled for a long time. There is no problem; they have been coordinated since the first integration of their strips. It was already regulated, I had nothing to do». «In the simulated environment, there is not wind component». «When we call for A/C speeds, we waste a lot of time on the frequency. I trust the information I have on the strip». «When there is a lot of traffic, there is no time to check the A/C speeds». Context «There was a narrow bottleneck: St-Yan at 115 and 150: The Clermont-Ferrand zone. If you enter it, it means your neighbour has to do a lot of coordinations and this gives him a lot of work. This is why we try to avoid it. At this time, my attention was mainly focused on this point: the LESPI point where all A/C come onto TALAR. I had forgotten what was going on on the other side. We often work like that. We focus on the point where the conflict/regulation is and after we come back on the rest but, for a while, our vision is focused on the problems, not peripheral».	PA – Routine violation of a procedure Working method, strategy, workload management Risk is taken, but managed	Yes

2.2 Summary Table of the Observations

N°	Simulation number	Questioned during the interview	Observer	A/C	Raw observations + Interviews	Detection	Recovery	Prevention	CA/PA/PD Error/Violation	Risk
1	ER-S1	✓	ATCO	LBED298	Clearance given to the A/C before the pilot actually called the controller (A/C not on the frequency)	No	No		PD: Error (Simulation bias)	No
2	ER-S1	✓	ATCO	AMM497	Talked in French to an English A/C	Pilot	No		PD: Error (Simulation bias)	No
3	ER-S1	✓	ATCO	AMM497	Following the previous undetected error: talked again to the A/C in English				PA (Simulation bias)	No
4	ER-S1	✓	ATCO	RGI655	Observer thought: «A/C shot to the wrong Control Centre», but in fact shot to the right sector according to the procedure				CA Standard procedure	No
5	ER-S1	✓	ATCO	RGI655	Following previous assumption, the observer noted: «Coordination at FL230, according to the strip, and A/C shot at FL190», but in fact correct action: A/C shot to the highest level in the sector				CA Standard procedure	No
6	ER-S1	✓	ATCO	LBED298 & BZ728FY	No speed assignment to two A/C in a catch-up situation (same FL, same A/C types)				PA: Routine violation	Yes
7	ER-S1	✓	ATCO	AFJP438	No readback (on pilot's heading)				PA: Routine violation	No
8	ER-S1	✓	ATCO	BZ728FY	Forgot that the pilot was already at 220Kts when ask to reduce speed to 250Kts	Yes: RC	Yes: RC	Yes: RC	PD: Error	Yes
9	ER-S1	✓	ATCO	FR705LO & AF395JJ	No speed assignment to two A/C in a catch-up situation: conflict between the A/Cs detected but no action to manage it before transfer to next sector				PA	Yes
10	ER-S1	✓	ATCO	BZ734AO & BZ738ZJ	No speed assignment to two A/C in a catch-up situation (same FL, same A/C types)				PA: Routine violation	Yes
11	ER-S1	✓	ATCO	BZ735JM & FGOPM	Late re-routing of an A/C after crossing with another A/C: first one given a heading back to its route immediately while second one waits for 2 minutes				PA: to save resources	No
12	ER-S1	✓	ATCO	BZ735JM	Call sign error: A/C called «Fox Juliet Mike» instead of «Brittair Juliet Mike»	No (Simulation bias)			PD: Error	No
13	ER-S1	✓	ATCO	PR447LO	No readback of pilot's heading				PA: Routine violation	Yes
14	AP-S1	✓	ATCO & PSY	BCS1708	Error on instruction immediately corrected	Yes	Yes		PD: Error	No
15	AP-S1	✓	ATCO	BCS1708	Use of incorrect phraseology: «FL50 instead of 5000 feet», immediately corrected	Yes	Yes		PA	No

N°	Simulation number	Questioned during the interview	Observer	A/C	Raw observations + Interviews	Detection	Recovery	Prevention	CA/PA/PD Error/Violation	Risk
16	AP-S1	✓	ATCO	BCS1708	Discussion with the PC about heading 80 and the standard route (change in the procedure)				PA: Simulation bias	No
17	AP-S1	✓	ATCO & PSY	UK627	Discussion and climbing instruction to FL100				PA: Simulation bias	No
18	AP-S1	✓	ATCO	FLT01	A/C climbed to FL140, with approval asked from PC (procedure followed)				CA	No
19	AP-S1	✓	ATCO	UK627	Assignment of a direct route (but not enough eventually to solve the conflict with another A/C)				PD: Error	Yes
20	AP-S1	✓	ATCO	UK627	Climb clearance towards FL120 to solve conflict but the PC suggests should go above to solve conflict				PA	Yes
21	AP-S1	✓	ATCO	UK627	Asks for the heading and assigns a 300° heading – solves a problem for next sector to solve conflict			Yes	PA	No
22	AP-S1	✓	ATCO	UK627	Climb to FL 160 to solve conflict (obs n°20) according to what the PC has suggested				PA	No
23	AP-S1	✓	ATCO & PSY	UK627	Gives a direct route and transfers the A/C to the next sector with another instruction (waits to be sure of the direct route)			Yes	PA	No
24	AP-S1	✓	ATCO	DEBRI	Climbs the A/C to FL 140 (because the other A/C is going to climb as well)				PA	Yes
25	AP-S1	✓	ATCO	DEBRI	Stops the A/C to FL 130				PA	No
26	AP-S1	✓	ATCO	DEBRI	Climbs the A/C to FL 140: strip not very explicit nor readable (FL 140 is now free)				PA	Yes
27	AP-S1	✓	ATCO & PSY	TYR377 & SAB3591	Two different flight levels (60 & 70) for two A/C that follow the same approach (not used to class C airspace, different from usual, violation of the rule)				PA: Violation	Yes
28	AP-S1	✓	ATCO & PSY	SAB3591	A/C descended to FL 60 (not possible to descend it before because of Class C airspace – VFR)				CA	No
29	AP-S1	✓	ATCO	TYR377	First instruction with 180° heading, 2nd instruction for speed, 3rd instruction to reduce speed, 4th instruction to transfer the A/C to next sector				PA	No
30	AP-S1	✓	ATCO	TYR377	Asks for the A/C speed (manages his/her image with the pilot)				PA	No
31	AP-S1	✓	ATCO	TYR377	Changes speed (doesn't want the A/C to be too far from its route)				PA	No
32	AP-S1	✓	ATCO	TYR377	Several instructions used (time taken to think things over one by one)				PA	No
33	AP-S1	✓	ATCO & PSY	HBGEA	Discussion with the PC regarding a coordination (doubt management, strip unclear)				PA	No

N°	Simulation number	Questioned during the interview	Observer	A/C	Raw observations + Interviews	Detection	Recovery	Prevention	CA/PA/PD Error/Violation	Risk
34	AP-S1	✓	ATCO & PSY	RNO232 & AFR3177	Asks for the A/C speeds (anticipates possible catch up situation)			Yes	PA	No
35	AP-S1	✓	ATCO & PSY	LMN246	Speed reduced to 200 Knots (normal regulation action for the arrivals)				CA	No
36	AP-S1	✓	ATCO & PSY	PRB507	Has forgotten to transfer the A/C – detected by the next sector – conflicts already solved	Next Sector	Yes		PD: Error	No
37	AP-S1	✓	ATCO	PRB507	No instruction asking the pilot to call when vertical beacon reached				PA	Yes
38	AP-S1	✓	ATCO & PSY	CFF626	Climbed to FL 180 to solve conflict with another A/C, to avoid levelling at FL 140, transferred to next sector when cleared from traffic at FL 130				PA	No
39	AP-S1	✓	ATCO	JEA1182	Climbed to FL 120 and right after to FL 150 (out of zone): conflict resolution with the previous A/C				PA	No
40	ER-S2	✓	PSY	?	Discussion with the PC – wants to ask the adjacent sectors to put the A/C on direct routes in order to manage the workload			Yes	PA	No
41	ER-S2	✓	ATCO & PSY	AMM497	Initial instruction to FL 80, then direct to Vienna with limitation to FL 110 (to comply with the approach's request). And discussion with the PC				CA	No
42	ER-S2	✓	ATCO & PSY	AF395JJ & THZ04	Conflict detection from the strips and then from the radar screen				PA	No
43	ER-S2	✓	ATCO & PSY	AF395JJ & THZ04	The PC forgets to mention the conflict and to solve it with the other sectors so that they send the A/C at another FL. The RC recovers the situation and solves the conflict				PA	No
44	ER-S2	✓	ATCO & PSY	AF438JP	Heading change of 20°, in order to prevent a problem with an arrival				PA	Yes
45	ER-S2	✓	ATCO & PSY	AF438JP	But doing so (44) creates a conflict with another A/C (Brittair). Doesn't take it back fast enough, so has to take it elsewhere for a while				PD: Error	Yes
46	ER-S2	✓	ATCO & PSY	AF438JP	Action on the AF instead of the Brittair, because the Brittair descends on arrival. Safer not to touch it, even if the AF complains				PA	No
47	ER-S2	✓	ATCO	AF438JP	Altitude instruction (to free the level in conflict first) and then another instruction for the heading			Yes	PA	No
48	ER-S2	✓	ATCO	Brittair	Calls A/C by two different names: «Brittair» and «Brittany». Not an error, does it often, tolerated by pilots				PA: Routine violation	No

N°	Simulation number	Questioned during the interview	Observer	A/C	Raw observations + Interviews	Detection	Recovery	Prevention	CA/PA/PD Error/Violation	Risk
49	ER-S2	✓	ATCO & PSY	AF438JP	Gives a direct route to Moulin, strategy very often used, to make the traffic more fluid. Takes the A/C back to its standard route				CA	No
50	ER-S2	✓	ATCO	FR705LO & AF395JJ	Assume the catch-up situation has not been detected, but the RC has detected it. The A/C are too far away and the next sector will take them like this				CA	No
51	ER-S2	✓	ATCO	FGOPM & B273JM	Conflict detection by the PC and then the RC. Resolution with heading assignment on the FGOPM, faster than the other				PA	No
52	ER-S2	✓	ATCO	FGOPM & B273JM	The resolution is not the best. I waited too long and couldn't do anything else then. Normally we should have called the sector so that the heading of the A/C be maintained				PD: Error	Yes
53	ER-S2	✓	ATCO & PSY	FGOPM & B273JM	Gives an information to the A/Cs, because they may see each other. Better for the pilots to know. Even if this time they cannot see each other, the pilot knows that I know what's going on			Yes	PA	No
54	ER-S2	✓	ATCO & PSY	FGOPM	A/C descended to FL 150 and then FL 110 with new heading. Heading could have been given with FL 150				PA	No
55	ER-S2	✓	PSY	FGOPM	Transfer of the A/C to the next sector out of zone (at the limit of the sector), and out of its route, because of late conflict resolution				PA	Yes
56	ER-S2	✓	ATCO	B2796XB	The PC replies to the pilot 7 seconds later, because of a discussion with the PC (to know which level can be given to the A/C)				PA	No
57	ER-S2	✓	PSY	B2796XB	Early transfer of the A/C, preferred practice in order to give space to the approach				PA	No
58	AP-S2	✓	ATCO	LI155UT	Instruction to reach FL 120, to avoid leaving the A/C above the crossing routes and make traffic more fluid				PA	No
59	AP-S2	✓	ATCO	SEU455D	First instruction: TDP and heading 350°, not understood by the pilot. Then instruction repeated and changed as follows			Yes	PA	No
60	AP-S2	✓	ATCO	SEU455D	Gives heading 330° to the A/C. The constraint is not TDP but not to go east another point further up (BERIE)				PA	No

N°	Simulation number	Questioned during the interview	Observer	A/C	Raw observations + Interviews	Detection	Recovery	Prevention	CA/PA/PD Error/Violation	Risk
61	AP-S2	✓	ATCO	SEU455D	Heading change to 345°: traffic around, and coordination with the feeder controller				PA	No
62	AP-S2	✓	ATCO	LI155UT	Instruction given: heading 330° and FL 100. Repetition of FL 100 in order to clear a doubt			Yes	PA	No
63	AP-S2	✓	ATCO	SEU455D	Descend to FL 60, disregarding the procedure, before crossing the conflicting routes, to make the traffic more fluid. The controller judges there will be no problem				PA: Violation	Yes
64	AP-S2	✓	ATCO	AFR3155	Complying to the procedure in dealing with the A/C: standard arrival. Here the FL 120 is imposed because the hills				CA	No
65	AP-S2	✓	ATCO	AFR3155	Anticipatory speed reduction to 220 Knots to wait in the stack (estimated waiting time: until 15), and then reduction to 200 Knots in order to leave another A/C before (strategy)				PA	No
66	AP-S2	✓	ATCO	AFR3155	Instruction FL 100 repeated, as the pilot could have forgotten (Simulation bias)				PA: Simulation bias	No
67	AP-S2	✓	ATCO	HBGEA	The pilot calls the RC by mistake. The RC understands immediately what happens and gives the right control frequency to the pilot				PA	No
68	AP-S2	✓	ATCO	TYR377	Clearance to descend to FL 70 in stack (waiting), according to the procedure (minimum level to stack A/C here)				CA	No
69	AP-S2	✓	ATCO	None	Radar breakdown: all A/C disappear on the screen, handled by the controller				PA	No
70	AP-S2	✓	ATCO	AF3155	A/C transferred too early to the feeder controller. Would have been better to wait 20 seconds to pass the crossing before transferring it				PD: Error	Yes
71	AP-S2	✓	ATCO	None	The RC asks if any further arrival on BRON is to be expected: anticipatory coordination done by the PC, as a long-term traffic regulation			Yes	PA	No
72	AP-S2	✓	ATCO	BZH879	Coordination with the feeder controller about transfer of the A/C exiting the stack. The feeder asks for transfers at heading 270°. The RC wants to separate two A/C with a transitory heading at 210° before transferring the A/C but the feeder doesn't understand			Yes	PA	No

N°	Simulation number	Questioned during the interview	Observer	A/C	Raw observations + Interviews	Detection	Recovery	Prevention	CA/PA/PD Error/Violation	Risk
73	AP-S2	✓	ATCO	AF3177	The feeder asks for a transfer at heading 230°. The RC doesn't react. He replies later by: «it's done» but regarding the previous request (72) of the feeder (heading 270°)				PD: Error	No
74	AP-S2	✓	ATCO	PR415DJ	The RC gives a very long instruction to the pilot with 4 elements in it, including a request to free FL 130 rapidly, because of a potential conflict. The pilot asks the controller to repeat.				PD: Error	Yes
75	AP-S2	✓	ATCO	TYR373	Violation of the phraseology: «one hundred» instead of «one zero zero»				PD: Violation	Yes
76	AP-S2	✓	ATCO	TYR373	A/C call sign confusion: TYR373 instead of TYR377				PD: Error	Yes
77	ER-S3	✓	ATCO	BZ-FY	Direct route assignment (and planning of the descent strategy)				CA	No
78	ER-S3	✓	ATCO	BZ-FY	Clearance to FL 80 without coordination: right estimation of the angle of descent, coordination not necessary and radar monitoring of the speed, distance)				PA	No
79	ER-S3	✓	ATCO	FGPOM	A/C strip not found immediately (PC's error detected) because it was on the wrong colour strip-carrier (red for climb instead of green for descent)				CA	No
80	ER-S3	✓	ATCO	AF-HF	Clearance of the A/C for FL 200, when it is almost at FL 200 already: conflict management with another A/C, the controller chooses a safe solution				PA	No
81	ER-S3	✓	ATCO	RG-AV	No communication with the A/C until the transfer at the limit of the sector				PA: Violation Simulation bias	Yes
82	ER-S3	✓	ATCO	BZ-XB	Pilot's hearback frequency mistake during transfer to approach				PA	No
83	ER-S3	✓	ATCO	PR-LO	Left heading assignment, to manage a conflict at the entrance of the stack. Anticipation of the approach request to reduce speed, safety and traffic management				PA	No
84	ER-S3	✓	ATCO	AF-HF	Asks the pilot's rate of the descent, to make sure the A/C will arrive at the right level in the stack (conflict management)				PA	No
85	ER-S3	✓	ATCO	PR-MI	Transfer to approach without coordination (absence of coordinated FL on the strip)				PA: Violation	Yes

N°	Simulation number	Questioned during the interview	Observer	A/C	Raw observations + Interviews	Detection	Recovery	Prevention	CA/PA/PD Error/Violation	Risk
86	AP-S3	✓	ATCO	SEU455D	First instruction «Descend FL 100 SAMSON GINET heading 350°» immediately corrected into «Correction, proceed STAR via TDP» (learning bias)	Yes	Yes		PD: Error	No
87	AP-S3	✓	ATCO	LI155UT	Instruction «Descent FL 100 SAMSON GINET TDP standard arrival»: good phraseology this time				CA	No
88	AP-S3	✓	ATCO & PSY	SEU455D & UKA627	No action: wait and see: very close crossing of a climbing A/C and an A/C on descent which belong to 2 different sectors. Close monitoring of the situation: works but not safe: configuration under test				PA	Yes
89	AP-S3	✓	ATCO	SEU455D	Conflict resolution (88): descend the A/C to FL 60, after the crossing point. Compliance with the procedure to deliver the A/C at FL 60 to the feeder controller				CA	Yes
90	AP-S3	✓	ATCO	THY377	The controller discusses with the PC and thinks for more than a minute to decide whether or not to exit the A/C from the stack earlier than planned. Finally, he decides to do nothing when he discovers another A/C				CA	No
91	AP-S3	✓	ATCO	Fox Lima	The controller suddenly discovers the A/C that is going to exit the stack: he had not seen the A/C before	Yes: PC	Yes		PD: Error	Yes
92	AP-S3	✓	ATCO & PSY	Radar Screen	The controller decides to suppress the departures from the radar screen (to clear the radar screen, lots of A/C) but keeps them on the PC's screen, to manage the risk (arrivals and departures are supposed to be separated)				PA	Yes
93	AP-S3	✓	ATCO & PSY	Radar Screen	Presses the wrong button to suppress the departures (one for departures and one for arrivals)	Yes	Yes		PD: Error Simulation bias	No
94	AP-S3	✓	ATCO	Stacks	Anticipatory exit of the A/C from the waiting stack (2 minutes before expected exit time) to please the PC. But the heading and levels given to the A/C are not easy to manage for the feeder controller: the strategy proves to be wrong				PD: Error	Yes
95	AP-S3	✓	ATCO	SAB3591	Anticipatory exit of the A/C from the waiting stack, other exit strategy southward to avoid conflict with previous A/C: good strategy this time				PA	No

N°	Simulation number	Questioned during the interview	Observer	A/C	Raw observations + Interviews	Detection	Recovery	Prevention	CA/PA/PD Error/Violation	Risk
96	AP-S3	✓	ATCO	BZH879	Anticipatory exit of the A/C from the waiting stack (4 minutes earlier than expected) because estimates there is space to send it to the feeder controller, but the rhythm is too high, additional work for the feeder				PA	Yes
97	AP-S3	✓	ATCO	RNO232	Anticipatory exit of the A/C from the waiting stack (3 minutes earlier than expected) - same reason as previous one				PA	Yes
98	AP-S3	✓	ATCO	AF3177	Anticipatory exit of the A/C from the stack and takes it along for a while to waste time (because too early)				PA	Yes
99	AP-S3	✓	ATCO	AF3177	Gives a 300° heading to the A/C to solve a conflict, as requested by the feeder controller				PA	No
100	AP-S3	✓	ATCO	THZ01	Re-displays the departure A/C tags on the radar screen because of an A/C that goes to another airport				PA	No
101	AP-S3	✓	ATCO	HY373	Anticipatory speed reduction to 220 Knots when entering the stack in order to solve a conflict with another A/C leaving the stack at the same time, without using the standard phraseology				PA	No

2.3 Summary Table of the Errors and Violations

Error/Violation identification: Ei = Error n°i / Vi = Violation n°i

Err./ Viol.	Obs. ident. number	Questioned during the interview	Observer	A/C	Raw observations + Interviews	Detection	Recovery	Prevention	CA/PA/PD Error/ Violation	Risk
E1	ER-S1 1	✓	ATCO	LBED298	Clearance given to the A/C before the pilot actually called the controller (A/C not on the frequency)	No	No		PD: Error (Simulation bias)	No
E2	ER-S1 2	✓	ATCO	AMM497	Talked in French to an English A/C	Pilot	No		PD: Error (Simulation bias)	No
E3	ER-S1 8	✓	ATCO	BZ728FY	Forgot that the pilot was already at 220Kts when ask to reduce speed to 250Kts	Yes: RC	Yes: RC	Yes: RC	PD: Error	Yes
E4	ER-S1 12	✓	ATCO	BZ735JM	Call sign error: A/C called «Fox Juliet Mike» instead of «Brittair Juliet Mike»	No (Simulation bias)			PD: Error	No
E5	AP-S1 14	✓	ATCO & PSY	BCS1708	Error on instruction immediately corrected	Yes	Yes		PD: Error	No
E6	AP-S1 19	✓	ATCO	UK627	Assignment of a direct route (but not enough eventually to solve the conflict with another A/C)				PD: Error	Yes
E7	AP-S1 36	✓	ATCO & PSY	PRB507	Has forgotten to transfer the A/C – detected by the next sector – conflicts already solved	Next Sector	Yes		PD: Error	No
E8	ER-S2 45	✓	ATCO & PSY	AF438JP	But doing so (44) creates a conflict with another A/C (Brittair). Doesn’t take it back fast enough, so has to take it elsewhere for a while				PD: Error	Yes
E9	ER-S2 52	✓	ATCO	FGOPM & B273JM	The resolution is not the best. I waited too long and couldn’t do anything else then. Normally we should have called the sector so that the heading of the A/C be maintained				PD: Error	Yes
E10	AP-S2 70	✓	ATCO	AF3155	A/C transferred too early to the feeder controller. Would have been better to wait 20 seconds to pass the crossing before transferring it				PD: Error	Yes
E11	AP-S2 73	✓	ATCO	AF3177	The feeder asks for a transfer at heading 230°. The RC doesn’t react. He replies later by: «it’s done» but regarding the previous request (72) of the feeder (heading 270°)				PD: Error	No

Err./ Viol.	Obs. ident. number	Questioned during the interview	Observer	A/C	Raw observations + Interviews	Detection	Recovery	Prevention	CA/PA/PD Error/ Violation	Risk
E12	AP-S2 74	✓	ATCO	PR415DJ	The RC gives a very long instruction to the pilot with 4 elements in it, including a request to free FL 130 rapidly, because of a potential conflict. The pilot asks the controller to repeat.				PD: Error	Yes
E13	AP-S2 76	✓	ATCO	TYR373	A/C call sign confusion: TYR373 instead of TYR377				PD: Error	Yes
E14	AP-S3 86	✓	ATCO	SEU455D	First instruction «Descend FL 100 SAMSON GINET heading 350» immediately corrected into «Correction, proceed STAR via TDP» (learning bias)	Yes	Yes		PD: Error	No
E15	AP-S3 91	✓	ATCO	Fox Lima	The controller suddenly discovers the A/C that is going to exit the stack: he had not seen the A/C before	Yes: PC	Yes		PD: Error	Yes
E16	AP-S3 93	✓	ATCO & PSY	Radar Screen	Presses the wrong button to suppress the departures (one for departures and one for arrivals)	Yes	Yes		PD: Error (Simulation bias)	No
E17	AP-S3 94	✓	ATCO	Stacks	Anticipatory exit of the A/C from the waiting stack (2 minutes before expected exit time) to please the PC. But the heading and levels given to the A/C are not easy to manage for the feeder controller: the strategy proves to be wrong				PD: Error	Yes
V1	ER-S1 6	✓	ATCO	LBED298 & BZ728FY	No speed assignment to two A/C in a catch-up situation (same FL, same A/C types)				PA: Routine violation	Yes
V2	ER-S1 7	✓	ATCO	AFJP438	No readback (on pilot's heading)				PA: Routine violation	No
V3	ER-S1 10	✓	ATCO	BZ734AO & BZ738ZJ	No speed assignment to two A/C in a catch-up situation (same FL, same A/C types)				PA: Routine violation	Yes
V4	ER-S1 13	✓	ATCO	PR447LO	No readback of pilot's heading				PA: Routine violation	Yes
V5	AP-S1 27	✓	ATCO & PSY	TYR377 & SAB3591	Two different F Levels (60 & 70) for two A/C that follow the same approach (not used to class C airspace, different from usual, violation of the rule)				PA: Violation	Yes
V6	ER-S2 48	✓	ATCO	Brittair	Calls A/C by two different names: «Brittair» and «Brittany». Not an error, does it often, tolerated by pilots.				PA: Routine violation	No
V7	AP-S2 63	✓	ATCO	SEU455D	Descend to FL 60, disregarding the procedure, before crossing the conflicting routes, to make the traffic more fluid. The controller judges there will be no problem				PA: Violation	Yes

Err./ Viol.	Obs. ident. number	Questioned during the interview	Observer	A/C	Raw observations + Interviews	Detection	Recovery	Prevention	CA/PA/PD Error/ Violation	Risk
V8	AP-S2 75	✓	ATCO	TYR373	Violation of the phraseology: «one hundred» instead of «one zero zero»				PD: Violation	Yes
V9	ER-S3 81	✓	ATCO	RG-AV	No communication with the A/C until the transfer at the limit of the sector				PA: Violation (Simulation bias)	Yes
V10	ER-S3 85	✓	ATCO	PR-MI	Transfer to approach without coordination (absence of coordinated FL on the strip)				PA: Violation	Yes

2.4 Summary of the HERA Analyses

The following table presents the results of the HERA analyses of the 16 errors (of 17) and 10 violations. Only one error, referred to as E15 (AP-S3 / 91) was not analysable with the HERA technique, since no action was actually performed by the controller. The controller had the intention to instruct an A/C to get out of the waiting stack before its expected leaving time and discussed this with the PC for about one minute. The RC was about to exit the A/C when he suddenly realised that there was another A/C getting out of the stack, which he had not seen. In this case, the RC had an intention of action, but didn't actually do it: this doesn't fall in the definition of a HERA error.

Err./Viol.	Obs. ident.	Detection	Recovery	Task	Information	ETs[4]	EDs[4]	EMs[4]	IPs[4]	Risk	Goal	CC1[4]	CC2[4]	CC3[4]	CC4[4]
E1	ER-S1 1	No	No	Instruction	Clearance	Action too early	Planning and decision-making **/** Memory **/** Response execution	Incorrect decision or plan / No recall of information / Timing error	Preoccupation	NR	-	SIMU			
E2	ER-S1 2	No	No	Instruction	Clearance **AND** Other language	Wrong action on right object	Response execution	Selection error	Problem of habits	NR	-	Pilot language	Complex traffic mix	Airspace design characteristics	SIMU
E3	ER-S1 8	Pilot	Pilot	Instruction	Clearance **AND** Transfer	Unnecessary act	Perception and vigilance / Memory	No detection of visual information / Memory capacity overload AND No recall of information	Monitoring failure / Preoccupation	R	-	Distraction			
E4	ER-S1 12	No	No	Instruction	Call sign	Incorrect information sent	Response execution	Incorrect information transmitted	Slip of the tongue	NR	-	Similar confusing call sign			
E5	AP-S1 14	On screen	New instruction	Control room communication between sector **AND** Instruction	Heading **AND** Conflict	Wrong action on right object	Planning and decision-making	Incorrect decision or plan	Failure to consider side effect	NR	-	SIMU	Lack of cooperation		

[4] ETs: Error Types – EDs: Error Details – EMs: Error Mechanisms – IPs: Information Processing levels – CC+digit: Contextual Conditions.

Err./Viol.	Obs. ident.	Detection	Recovery	Task	Information	ETs[4]	EDs[4]	EMs[4]	IPs[4]	Risk	Goal	CC1[4]	CC2[4]	CC3[4]	CC4[4]
E6	AP-S1 19	On screen	New instruction	Instruction	Heading **AND** Conflict	Action too late	Response execution **/** Planning and decision-making	Timing error / Misjudge aircraft projection	Spatial confusion / Failure to integrate information	R	-	Airspace design characteristics	SIMU	Airspace complexity	
E7	AP-S1 36	Adjacent sector	Transfer	Radar monitoring	Transfer	Omission	Memory	Forget a plan action	Preoccupation	NR	-	Excessive traffic load	SIMU		
E8	ER-S2 45	On screen	New instruction	N/A (conflict processing)	Heading AND Conflict	Action in wrong direction	Planning and decision-making	Misjudge aircraft projection	Failure to integrate information	R	-	SIMU			
E9	ER-S2 52	No	No	N/A (conflict processing)	Conflict	Action too late	Planning and decision-making	Late decision or plan	Fail to recognise risk	R	-				
E10	AP-S2 70	On screen	No	Coordination between sectors	Coordination AND Transfer	Action too early	Planning and decision-making	Incorrect decision or plan	Fail to recognise risk AND Failure to recognise side effect	R	-	SIMU			
E11	AP-S2 74	No	No	Coordination between sectors	Heading	Unclear information sent	Response execution	Unclear information sent	Unclear speech	NR	-	No assistance	Unclear methods	No confidence	
E12	AP-S2 74	No	No	Instruction	Descent AND FL AND Holding	Unclear information sent	Planning and decision-making	N/A	Incorrect priority of task	R		Pilot-controller communication - Complexity in ATC transmission			
E13	AP-S2 76	No	No	Instruction	Call sign	Incorrect information sent	Response execution / Memory	Incorrect information transmitted / Misrecall of information	Slip of the tongue / Preoccupation	R	-	SIMU	Underload		

Err./Viol.	Obs. ident.	Detection	Recovery	Task	Information	ETs[4]	EDs[4]	EMs[4]	IPs[4]	Risk	Goal	CC1[4]	CC2[4]	CC3[4]	CC4[4]
E14	AP-S3 86	Self-monitoring	New instruction	Instruction	Heading	Incomplete information sent	Memory	Misrecall of information	Insufficient learning AND Rarely used information	NR	-	Training and experience - Novel situation	SIMU		
E16	AP-S3 93	On screen	Undo/redo	HMI input & functions	ATS equipment AND Primary radar / touch	Right action on wrong object	Response execution	Selection error	Problem of similar look	NR	-	SIMU			
E17	AP-S3 94	Adjacent sector	New instruction	Planning	Heading	Wrong action on right object	Planning and decision-making	Incorrect decision or plan	Fail to integrate side effect	R	-	SIMU			
V1	ER-S1 6	-	-	Coordination between sectors	Flight level and Speed	Routine violation	-	-	-	R	Workload management	Excessive traffic load			
V2	ER-S1 7	-	-	Readback	Heading	Routine violation	-	-	-	NR	To limit the use of R/T	Excessive traffic load	Distraction job-related		
V3	ER-S1 10	-	-	Coordination between sectors	Flight level and Speed	Routine violation	-	-	-	R	Workload management	Excessive traffic load			
V4	ER-S1 13	-	-	Readback	Heading	Routine violation	-	-	-	NR	Workload management	Excessive traffic load			
V5	AP-S1 27	-	-	Instruction	Descent	General violation	-	-	-	R	Airspace configuration	Airspace design characteristics	Restrictive procedure		
V6	ER-S2 48	-	-	Instruction	Call sign	Routine violation	-	-	-	NR	Goal unidentified				
V7	AP-S2 63	-	-	Instruction	Descent	General violation	-	-	-	R	Workload management of the adjacent sector	SIMU	Procedure unclear	Underload	
V8	AP-S2 75	-	-	Instruction	Flight level	Routine violation	-	-	-	R	Goal unidentified	SIMU			
V9	ER-S3 81	-	-	Instruction	Clearance	General violation	-	-	-	R	Goal unidentified	SIMU			

Err./Viol.	Obs. ident.	Detection	Recovery	Task	Information	ETs[4]	EDs[4]	EMs[4]	IPs[4]	Risk	Goal	CC1[4]	CC2[4]	CC3[4]	CC4[4]
V10	ER-S3 85	-	-	Coordination between sectors	Transfer	General violation	-	-	-	R	Workload management of the adjacent sector	SIMU			

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