TWENTYFIFTH EUROPEAN ROTORCRAFT FORUM

Paper n° F3

EUROPEAN FRAMEWORK FOR THE DESIGN OF INTELLIGENT TRAINING AIDS

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SEPTEMBER 14-16, 1999
ROME
ITALY

ASSOCIAZIONE INDRUSTRIE PER L'AEROSPAZIO, I SISTEMI E LA DIFESA
ASSOCIAZIONE ITALIANA DI AERONAUTICA ED ASTRONAUTICA

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ABSTRACT

After a general presentation of EUCLID and CEPA 11, this paper presents the scope and some considerations of EUCLID CEPA 11 RTP 11.9 "Intelligent Training Aids", a project which started in January 1998.
The first phase of the study was focused to provide the scientific and technical bases for the further developments, to analyse literature on military education and training, to assess and characterise existing training devices in the participating countries.
A global training model is proposed. The identified model allows to define the main concepts of interactions between the training system and the actors taking part in the training.
The paper describes the model derived from works in the fields of human engineering and psychology. The model is adapted from what has been developed to model the operator monitoring a complex system.
An analysis of general instruction tasks found in military training systems is then described.
Lastly, possible applications of ITA are deducted from this cognitive approach, as well as from the survey of fielded systems and the Consortium's experience.

This work is partially funded by the MoDs of France, Germany and Italy, in the framework of the EUCLID CEPA 11 program.

INTRODUCTION

This paper presents the scope and some initial considerations of EUCLID CEPA 11 RTP 11.9 "Intelligent Training Aids".

The first goal of the study is to provide the scientific and technical bases for the further developments, by researching literature on military education and training, assessing and characterising existing training devices in the participating countries.

During the genesis of this project, two opposite approaches were considered.

The first approach was technology driven; it would have led us to answer questions such as: what can Artificial Intelligence, Fuzzy Logic, or other techniques, offer ?

This method would have revealed to be well suited if the goal of the study had been to improve existing training aids by automating some of the instructor's tasks, but the aim of the Management Group was more ambitious.

To imagine new, intelligent training aids, it has been deemed necessary to identify which cognitive processes take place among the actors of the training, and to analyse the nature of the interactions between these actors and the training systems.

This led to the selection of a cognitive approach, complemented by field surveys, which are presented in the following sections.

EUCLID BACKGROUND

European Co-operation for the Long-term in Defence (EUCLID) is a structured approach to European defence technology development which started in 1988 and is now conducted under the aegis of WEAO by the WEAO Research Cell (WRC) in Brussels.

EUCLID consists in eleven Common European Priority Area (CEPA). Among these, CEPA 11 addresses Defence Modelling and Simulation Technologies. It defines priority subjects which are being addressed in Research and Technology Projects (RTPs).

CEPA 11 is comprised of the following bodies:

- the Steering Committee, chaired by the Netherlands, has members belonging to the MoDs of twelve European Nato countries, and a secretary, Mr Sten Jensrud, WRC,
- Management Groups (MoD representatives) manage the RTPs and report to the Steering Committee,
- the CEPA 11 Industrial Group (CIG 11), representing EDIG (European Defence Industry Group), advises the Steering Committee and reports to EDIG and to the companies belonging to national CIGs.

More detailed information can be found in Merison (1998).

PRESENTATION OF CRITIAS

CRITIAS, Co-operative Research in Intelligent Training and Instructional AidS, officially known as RTP 11.9 "Intelligent Training Aids", is a 3-nation project undertaken by France, Germany and Italy, France being the leading country. The contract has been awarded on 26 Jan 1998 and the duration of the project is three years.

The industrial Consortium is led by the French company SOGITEC, with the participation of CAE Elektronik GmbH for Germany, AGUSTA SpA and EIS SpA for Italy, and Thomson Training & Simulation (TT&S) as the other French partner.

Expected results of CRITIAS

The main results of CRITIAS will be the following:

- a formally defined set of Intelligent Training Aids which are coherent and applicable to many training systems,
- presentation and evaluation of Intelligent Training Aids demonstrators developed for specific training devices, for which users have a significant interest,
- a rationale supporting the above definition and developments.

What are the benefits of Intelligent Training Aids ?

Intelligent Training Aids are methods and tools for military training systems that will:

⇒ improve the quality of instruction,
⇒ provide the instructor with means of better preparing and following the training session, and preparing and executing briefing and debriefing,
⇒ support standardised instruction, and objective assessment and documentation,
⇒ reduce instructor workload and avoid distraction from the pedagogical tasks,
⇒ provide effective scheduling guidance within a set of training means and their sequential use,
⇒ include specialised expertise where necessary or needed for instructor support,
⇒ support self training and/or instructor-controlled training.

Application domain of Intelligent Training Aids

Intelligent Training Aids will effectively support technical and tactical control of military training devices which may be:

- Computer Based Training systems,
- individual or crew simulators of various complexity (PTT, FMS),
- tactical team training systems and simulator networks.

Training requirements of Air Force, Army and Navy will be addressed.

Structure of CRITIAS

CRITIAS is divided into four work packages:

WP1 Analysis of different training devices and their instructional use
WP2 Definition of Areas for Intelligent Training Aids Application
WP3 Definition of Requirements and Specification of Intelligent Training Aids
WP4 Development, Integration and Demonstration of Intelligent Training Aids

The following sections present some insight gained during the first stages of WP 1 and WP 2.

MODELLING TRAINING

The study focuses on the military training of a person or team through an initial (CBT) or advanced (PTT, FMS) training system. In order to build a theoretical framework for the study, we have investigated existing training models in the literature and designed a general training model as a baseline.

This model, depicted in figure 1, is comprised of the training system, which we define as a technical system encapsulated by training aids, interacting with the training actors. The technical system can be the real system or a simulation of the real system. Examples are a simulated cockpit, or a manual presented in a digital form (for CBT). The actors are the following:

- a trainee, who has to learn the use (for operation or maintenance) of a complex system,
- an instructor who is interacting with the trainee, mainly to help or assess the trainee,
- an expert (usually not present during training, so shown in a dotted line rectangle), who brings expertise to the training aids or to the instructor, as well as benefit from the experience gained by the instructor (and to a lesser extent by the trainee, this is not represented in the figure).

Interactions of the instructor with the system are possible, for example through the use of an IOS for a simulator or through a lesson planning system for a CBT. Interactions of the trainee with the system can also be enhanced, as for example if hypertext is used to read the computerised manual mentioned earlier or in a CBT lesson. In this latter example, the instructor may be virtual.

The knowledge that the instructor and expert possess pertains to three areas:

- System (how to operate the training system)
- Pedagogical (how to transfer knowledge to the trainee in an efficient way)
- Operational (how to use or maintain the "real" complex system)

We now can define an Intelligent Training Aid (ITA) as a function resulting from the transfer of a cognitive process from the instructor or the expert to the training aids.

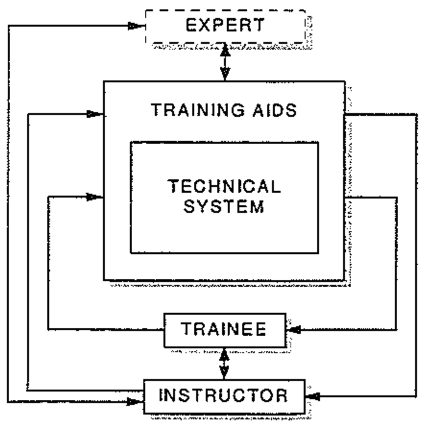
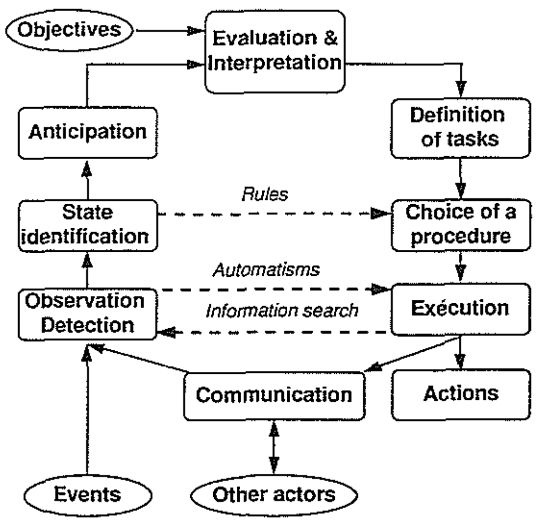


Figure 1: General training model

A trainee model

In this section, we are interested in modelling the trainee learning to operate a complex system. We take as a representative example the training of the operational activity for a military aircraft pilot, who has to achieve the goals of his assigned mission while maintaining a relative safety.



a complete revision.
The analysis of the representation, the objectives and the constraints results in a ***planning*** of the actions to undertake, in the determination of the relevant ***procedure***, then finally in the action itself. This action can be:

- an action resulting in an evolution of the state of the piloted system itself (modification of trajectory, use of the weapons...); in the following, this last concept will be termed ***action***,
- a ***communication*** with the other actors with whom the pilot co-operates,
- or finally a new ***search for information.***

In addition, this process is permanently simplified by many "short-cuts", which decrease the total workload of the pilot. An observation can start an execution quasi immediately: this happens for phenomena which, to respect strong temporal constraints, are treated on a reflex mode, or for routine activities which can be ***automated***.

A new state of the process may not require to reinterpret or re-evaluate the situation as a whole: the solution to this evolution is perfectly known, and is treated by the application of more or less formalised ***rules***.

The suggested model, illustrated by figure 2, is very largely inspired by the work of Rasmussen (1987), already adapted by Van Eslande (1997).

Figure 2: A trainee model

During the execution of a mission, the pilot is confronted with difficulties which can disturb the above-described process and generate abnormal operations.

A somewhat abstract and theoretical definition of the role of the instructor would consist in affirming that his objective is to modify the behavioural model of his trainee.
In a more concrete way, this means that it is necessary that the trainee acquires:

- the theoretical prerequisites, to be able to create a mental representation of the system,
- elementary skills necessary to action,
- elementary skills necessary to observation,
- elementary skills necessary to communication,
- reflexes,
- procedures,
- the capacity to create, to share, and to call into question, a representation of the situation,
- capabilities for planning,
- and finally, a capability to distribute his tasks, i.e. to treat at the procedure level what pertains to procedures, at the reflex level what pertains to reflexes.

Lastly, these abilities must be used in an increasingly complex environment.

Such a framework of training is more ambitious than a conventional definition, which is only concerned into directly observable results of the actions of the trainee.
In practice, innumerable difficulties may be encountered; by way of illustration:

- the already quoted example, on the rules applied in low altitude flight, shows that the "good procedure" concept relates to expertise, which is only exceptionally formalised; this remark also applies to "good planning",
- how to check the application of a procedure?
  On this subject, the above mentioned example on low-altitude flying is enlightening. Amalberti (1996) points out that the trainee pilot applies a method which is mostly relative to planning, in the sense that he tries to continuously correct an error whereas an expert pilot would react to thresholds. An analysis of the results of the two control strategies (threshold based process or continuous regulation) should be very sensitive if indications are to be deduced on the pilot's level of expertise.
- Generally speaking, how to observe the pilot's behaviour ? What are his intentions ? What information is he looking for ?

This stresses the fact that an instructor may need a wide range of aids, with various objectives, which have to be assessed in relation to the instructor's tasks, as developed in the following sections.

We have also investigated **Team Training**, for which Silverman, Spiker, Tourville, and Nullmeyer (Silverman et al., 1996) have proposed a conceptual model, which includes operational definitions for aircrew co-ordination, team performance and mission performance models.

INSTRUCTION TASKS

We first went through a *review of existing literature and practices* on instructional and pedagogical issues of military education and training. Focusing on instruction tasks, most of the findings related below come from the EUCLID CEPA 11, RTP 11.1 (MASTER) and RTP 11.3 projects.

Field Orientation findings

The instructor is considered the "heart" of the training programme. He is the link between theoretical knowledge and the real world. Six different instructor profiles can be deduced from the tasks instructors have to fulfil during a training session. These are:

- planning instructor,
- test instructor,
- briefing instructor,
- exercise instructor,
- analyst instructor,
- debriefing instructor.

It is assumed that a team of instructors can perform all above mentioned tasks. During an exercise one or several instructors may play the role of participants in the scenario, co-ordinated by *a chief instructor.*

An important instructor's function is to help the trainee to transform the skills learned on a training system onto the actual device. This transfer is greatly improved by the instructor's experience and his capability to advise trainees.

Instructors then build up a lot of expertise while teaching with the simulator. In most cases such expertise is not recorded anywhere and get lost when the instructor leaves, which, due to the job rotation system used in most military services, occurs rather frequently.

Often instructors are not involved in mission and task analysis, but usually they are the ones with relevant knowledge. Usually the specification of a training programme is system-driven, not training driven.

Furthermore learning goals are adjusted to the possibilities provided by the training system, not from a mission and task analysis. This might be the reason why so little facilities are available to support the instructor in evaluation of performances and provision of effective feedback.

Prior to focusing on *classifying the instructor's tasks* we felt the need to fix the process of instruction design within a *theoretical framework.*

An Instruction Design Framework

Instruction can first be defined as the provision of information extrinsic to the (training) task in order to enhance/induce learning in trainees.

An *instructor* is then an individual engaged in/assigned to delivering instruction.

Each time he (or she) prepares for the instruction a teacher has to determine what, when and how to teach, i.e. what a trainee has to accomplish, what the objectives are, what the teaching behaviour will be, what the schedule is, how to arrange the instructional material, how to motivate the trainee, how to provide appropriate feedback and how to evaluate the trainee's work.

Approaches to achieve these tasks are called "*teaching styles*".

The design of the instructional system includes definition of the events that take place during the instruction, and the sequence of these events.

Based on a cognitive model of a human's learning process, the proposed set of instructional events consists of nine activities (Gagne, 1985). These are:

- gain the attention of the trainee,
- Inform of the objective,
- stimulate recall of prior learning,
- present the information,
- provide learning guidance,
- elicit performance,
- provide feedback,
- assess the performance,
- and enhance retention and transfer.

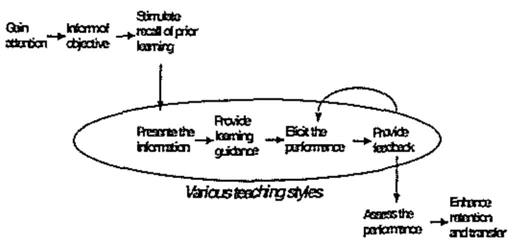


Figure 3: instructional events

The oval set reflects a particular approach to present information (a teaching style).
When followed, these events are intended to promote the transfer of knowledge from perception through the stages of memory.

Towards a Classification of Instructor's tasks

Instructors are usually considered as teachers whose primary task is to provide instruction to the trainees, before, during and after training. However, in most cases the instructor is also responsible for administrative and operational duties that are part of designing and maintaining a training programme, but also to run and to maintain the training system itself. All these responsibilities and duties combined result in a wide range of tasks of today's instructors.
To classify the instructor tasks five categories were defined.

Administrative and organisational tasks

General organisational and administrational tasks related to the training and training programme. This includes the design of scenarios, but also the management of the trainee database.

Pedagogical tasks

Tasks that especially involve the pedagogical knowledge of an instructor, e.g. to help the trainee to transfer the skills learned on the simulation system onto the actual device.

Instructional tasks

Tasks to execute a training session, e.g. to change display/instrument settings available to the trainee.

Additional tasks

All tasks that can't be assigned to one of the above categories, e.g. to play the role of an active participant in the scenario (like an opponent, a wing-man or a co-pilot).

Above tasks have not necessarily to be fulfilled during all training sessions and from all instructors. The tasks an instructor has to perform will vary depending on the kind of training device, the training objectives, the characteristics of the trainee, the number of trainees, the number of instructors, etc.
Whatever the kind of knowledge involved, any of the above mentioned tasks can, to a certain extent, cause distraction from the actual task of an instructor: *to provide an optimum training to the trainees.*

INTELLIGENT TRAINING AIDS

The first step is to review *existing training devices and training aids* used within military organisations in order to focus on significant areas of improvement related to possible Intelligent Training Aids. Focusing on different domains, most of the findings below come from a survey of in services training systems and interviews to instructor conducted for RTP 11.9.

Possible expert ITA

Bringing some expertise to the training aids requires modelling knowledge and skills possessed by a subject matter expert. Expert training aids encompass the different kinds of knowledge involved in training and instruction activities, which can be summarised in four different areas (Orey and Nelson, 1991; Orey, 1993; Mitchell, 1993) as illustrated in figure 4.

An expert training aids is based on knowledge about what is being taught, the *domain knowledge*, knowledge about the level, the strengths and weaknesses of a particular trainee at a particular moment, the *trainee knowledge*, knowledge about instructional strategies, the *pedagogical knowledge*, knowledge about the way to present information to and get information from the trainee, the *instructional knowledge*.

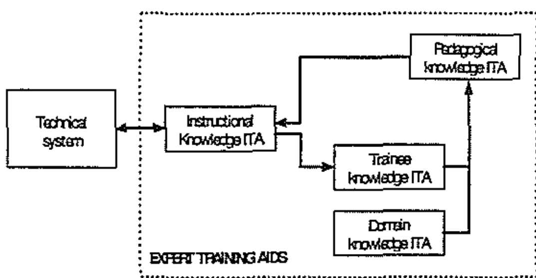


Figure 4: expertise areas

Domain knowledge

Expert domain knowledge addresses the behaviour (in terms of both actions and reactions) expected from an experienced trainee/crew in a given situation.
In conventional PTT and FMS training systems, such expertise remains the property of

instructors and is not transferred to the system. The expertise is built up while teaching with the simulator and it often is lost when the instructor leaves.
A possible axis of development for ITA is then to provide the training system with a formalised representation of the domain knowledge, e.g. a set of «fuzzy logic» rules that reflect a reference behaviour extracted from subject matter experts.

Trainee knowledge
Trainee knowledge addresses the representation of what the trainee knows about the domain and what he/she does not know, just like a human teacher being able to monitor the trainee's knowledge status. Such knowledge has then to be updated continuously by the instructor.
Monitoring and updating the trainee's knowledge remains however a difficult task, a possible axis of development for ITA is at least to provide the training system with the entrance and expected levels of proficiency of the trainee and with data computed from the trainee's behaviour for a further comparison with the expert domain knowledge model.

Pedagogical knowledge
Expert pedagogical knowledge addresses the expertise needed to teach the domain knowledge in an efficient and adequate way.
In conventional training systems (e.g. CBT) most of these decisions are taken beforehand by scenario designers. Decisions are pre-programmed and the way of teaching is usually not adapted during the lessons to a particular trainee's performance.
A possible axis of development for ITA is then to provide the training system with capabilities to adapt its teaching strategy dynamically, and to react or to help the instructor to react adequately to the performance of the trainee.

Instructional knowledge
Expert instructional knowledge addresses both the presentation to the trainee of the task environment, the exercises and the instructional interventions by the system or the instructor, as well as the recording of the trainee's responses and other performance variables.
A possible axis of development for ITA is then to provide the trainee with augmented cueing and feedback tutoring facilities, as well as inclusion of functional explanations in the technical system based as much as possible on self-explaining interfaces.

Levels of expertise for ITA

During the course of RTP 11.9 different levels of expertise for Intelligent Training Aids were defined. The definition follows the idea of increasing complexity of an intelligent system and increasing abstraction of the inputs into the system, thus reducing the instructor's workload during training level by level.

Intelligence can be defined as the ability to learn, to reason and to understand. For a technical application this means that an intelligent system itself has to have the ability to analyze data, to understand the data, to find commonalities and to draw conclusions from this point.

Figure 5 shows an intelligent system, it is possible to recognize that the main elements are the database and the rule base. The rule base determines how new data and rules have to be acquired. The significant part is the intelligent system's ability to change its data base <u>and</u> rule base by itself. That means the system will be able to learn.

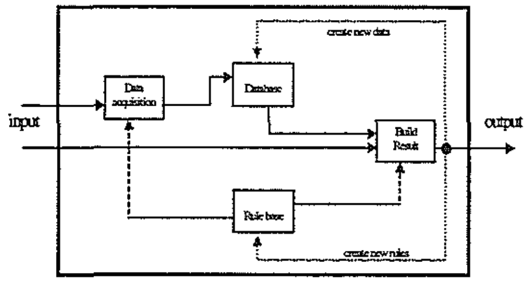


Figure 5: Intelligent System

Transferring this model to the application of an optimum intelligent training aid, the system must have the expert knowledge of an instructor which was described above: domain, trainee, pedagogical and instructional knowledge.

In respect to training the gathered knowledge will allow the intelligent system to analyze, to understand and to assess previous and current training situations and to foresee upcoming situations.

The figure shows an intelligent system at its full extent, and - following the definition of intelligence given above - it is the only system that can be strictly called intelligent. However, for the specification of ITA, the following levels were defined to individuate increasing complexity of an ITA application and discriminate on technological efforts capable to sustain them. The different levels represent different achievable levels of ITA. The levels are:

0) Ergonomic design of a man-machine-interface
1) Applying simple and static rules to the input
2) Increased flexibility by taking into account information from the data base
3) The system supports automatism to select compound actions from a database
4) The system is able to expand its database by means of fixed rules
5) The system is capable to analyze its database, find commonalities and expand it, creating new data
6) The system is capable to create new rules

In respect to the expert knowledge that is involved in training and instruction activities (see expert ITA described above), the intelligent system has at least to incorporate expert knowledge starting from level 2. Beside the instructional knowledge, which is needed to present information to and get information from the trainee, the ITA has to have knowledge about the actions and reactions expected by the trainee (domain knowledge). As these actions can depend on the trainee's representation of the domain, trainee knowledge has to be incorporated into the ITA for a more precise and adequate assessment. The pedagogical knowledge, which addresses instructional strategies, has to be transferred to an ITA to promote the ability of automatic and intelligent intervention or to provide training systems with the capability of automatic and dynamic adaptation of teaching strategies.

Toward a classification of ITA

In today's training systems, there is a distinct need for improved tools supporting the instructor in all the training phases that for our study have been distinguished in preparation, briefing, supervision, assessment and debriefing.
These training phases are common to every type of existing training devices (e.g. CBT, PTT, FMS, C3I) and consequently a classification of ITA can be proposed.

For the purpose of ITA classification we found a global approach would be more suitable to reach a comprehensive definition, being the analysis based on detailed investigation to find out either instructor's expectation inside the military organisations or known possible areas of technological research to support enhanced tool functionalities for the technical system. Following that approach General Areas of Interest have been identified for the ITA. Common aspects in the instructional needs respect to the training phases were logically grouped into GAoI software components. General Areas of Interest ITA are respectively:

- ⇒ Training Design
- ⇒ Automatic Intervention Support
- ⇒ Scenario Design
- ⇒ Assessment Support.

As first consequence of the above definition we recognised common instructional needs, i.e. "user requirements" to be supported by a GAoI ITA, covering more than one instructional phase whenever the instructor's tasks are correlated. As an example having an intelligent tool to author a scenario taking into account the specific training objectives (e.g. procedural, combat, tactical) could be also of interest for assessment/debriefing purposes and support the programming of assessment criterias/rules during the early stage of training design.

<u>*Training Design*</u>

The training design GAoI ITA high level functional requirements are training program authoring, training program optimisation and training objectives authoring. That means an ITA tools in this case should be at least capable of all the following:

a) provide means to define training programs in terms of courses, subjects, training objectives, temporal data, scenarios, training devices
b) provide means to evaluate training programs and their constituent elements (training objectives, scenarios, trainee performance, training devices) in accordance with different instructional strategies
c) provide means to document instructor defined criteria into the training program definition
d) provide means to track current trainee performance and optimize training programs accordingly
e) provide means to suggest training programs modification in accordance with investigated trainee's performance deficiency
f) provide means to suggest training programs modification in accordance with inadequate training devices capabilities
g) provide means to validate the correctness of a training program
h) provide means to optimize training programs on an individual basis, if requested
i) provide means to manage trainee info into a centralized database
j) provide means to document trainee competence and skills into a centralized database

k) provide means to import/export data from the training design data base to/from the training devices scenario and trainee DBs.

Automatic Intervention Support

The automatic intervention support GAoI ITA high level functional requirements are automated briefing, augmented feedback and intervention support. That means an ITA tools in this case should be at least capable of all the following:

a) provide means to support augmented feedback to trainee in accordance with the specific difficulties
b) provide means to modify training environment accordingly to current trainee skills
c) provide means to support tutor training environment
d) provide means to adapt level of training on current trainee performance and learning acquisition
e) provide means to support augmented feedback to instructors on current training situation for conditions/procedures evaluated of relevance for instructor's intervention
f) provide means to support automated briefing on training objectives using functions embedded within the training system itself
g) provide means to support instructor intervention mainly on critical situation
h) provide means to support analysis of the current training situation and tracking of instructor choices
i) provide means to record feedback to trainee as a way to maintain awareness of current trainee's performance
j) provide means to analyse and classify the errors made by the trainee.

Scenario Design

The scenario design GAoI ITA high level functional requirements are scenario authoring, scenario testing and evaluation, interpretation of external (intelligence) data, import/export of data. That means an ITA tools in this case should be at least capable of all the following:

a) provide means to define/design a scenario using an high-level hierarchical tool that does not require specific programming competencies
b) provide means to test and evaluate a scenario using a dedicated expert tool
c) provide means to define and program assessment criteria and/or automatic actions/events
d) provide means to support analysis and evaluation of scenario situation with particular relevance to prediction of possible scenario evolution
e) provide means to support analysis of the current scenario situation to support possible instructor's intervention and supervision
f) provide means to design a new scenario using collected data from debriefing
g) provide means to support briefing/debriefing and generate briefing and debriefing materiel
h) provide means to generate take home packages
i) provide means to import/export of external data.

Assessment Support

The assessment support GAoI ITA high level functional requirements are relevant to a more objective and standardised trainee evaluation, training programs/scenario re-authoring on the base of assessment results. That means an ITA tools in this case should be at least capable of all the following:

a) provide means to re-design a new scenario using assessment results
b) provide means to support assessment on the base of rules/criterias for different type of training (i.e. initial/advanced/tactical/team)
c) provide means to program assessment rules/criterias
d) provide means to support instructor assessment by means of specific contextual info pages
e) provide means to support automatic evaluation of procedures
f) provide means to support instructor in the analysis of assessment data by means of specific expert tool for different type of training (i.e. initial/advanced/tactical/team)
g) provide means to correlate assessment results on subsequent steps of a training program
h) provide means to identify relevant sequence of a training session for debriefing
i) provide means to generate debriefing materiel
j) provide means to optimise training program on the base of assessment results.

The functional requirements stated above for each GAoI ITA were being detailed into software requirements and general specifications in the next project steps.

CONCLUSION

We discovered the cognitive approach fully addresses the core of the problematic. Regrettably, doing the literature survey for this first task of the study, we found that there are few papers on military training addressing the instructor, the trainee and the training system

with a systematic approach, which is what we have tried to achieve.
Notably, the contribution of RTP 11.1 to CRITIAS has proved to be a major one for it has allowed to build the foundation of the framework the Consortium will use and enrich throughout the study.
The cognitive approach also helps to zoom out the idiosyncratic features of existing training aids and/or instructors' praxis, analysed in RTP 11.2 and RTP 11.3, and then makes it possible to formalise a more general framework of modern military training.
This framework provides guidelines to imagine innovative Intelligent Training Aids, that will improve the efficiency and the standardisation of the whole training process. At that stage, state of the art technology can be brought in to design ITA.
It will then be left to the craftsmanship of the *Pedagogical Architect* (Mayou, 1998), mastering both the technological aspects and the pedagogical objectives, to design the training means in full coherence with the training course.

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