Is refresher training of air traffic controllers adequate to meet the challenges of emergencies and abnormal situations?

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Abstract
The fundamental assumption behind the refresher training of air traffic controllers is to impart them with the required skills and knowledge to meet successfully the wide range of challenges imposed by emergencies and abnormal situations. The purpose of this study was to test this assumption. Research in emergencies and abnormal situations training in the Air Traffic Control, (ATC) system is limited as normal operations and error taxonomies attract the majority of the efforts. An observational field study was conducted using Cognitive Systems Engineering (CSE) research principles. A prototype set of individual and team-level cognitive strategies was used to investigate dyadic teams of operational controllers during real and simulated emergencies and abnormal situations in a major European Area Control Centre. A significant reduction of performance was observed during the management of certain categories of abnormal situations where the escalation pattern called for rapid interventions from the Executive Controller position. Cases with less stepper escalation patterns were handled successfully. The refresher-training curriculum was technically oriented and focused in those categories where better performance was displayed and rapidity of interventions was not an issue. Results indicate a considerable gap between formal training requirements and unattained operational demands that may lead to safety implications. An advanced safety-training course focusing on cultivating coordination, resilience and affordances skills that appeared to be lagging might bridge the gap.

INTRODUCTION

The ATC system is a highly complex safety critical system with countless anticipated and unanticipated paths to failure. As the controllers become sensitive to the potential paths to failure, they develop failure-sensitive strategies to counteract failure paths. An emergency presents controllers with many challenging issues. Is the situation unusual and how far to pursue monitoring of the situation? As soon as a disturbance is detected, a problem-to-be-solved is formulated and the need to re-plan for the situation becomes prominent. To respond to an emergency, controllers should demonstrate problem-detection skills and re-planning strategies. As an occurrence evolves over time, new threats may appear whilst current threats may change their demands. The need for gathering new information to fill in the gaps, correct explanations, clarify assumptions and evaluate candidate hypotheses is amplified. This calls for strategies in recognizing the
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situation, anticipating how the situation will evolve in future, and how to manage uncertainty. On the other hand, the joint performance of controllers and supervisory systems is equally challenged in an emergency. ATC requires synchronization of many inter-dependent activities within a short time window and this calls for demonstration of joint cognitive strategies. Coordination is the main prerequisite for synchronization but it comes at the cost of information exchange. New tasks are added and ordinary prioritization is altered. Therefore, increased workload must be balanced by intra-team reallocation of tasks. In addition, safety critical situations are not tolerant of errors, which imply that controllers should “engineer” their own opportunities for error detection and correction.

Annual refresher courses for operational air traffic controllers are aimed at training and equipping them with the required skills and knowledge to meet successfully the demands of emergencies and abnormal situations (EAS). There is an assumption that completing a refresher course, where classroom lessons and simulator scenarios cover standardized procedures for a range of abnormal situations, will prepare controllers to manage effectively similar situations that may encounter in actual operations. Controllers are expected to build up an inventory of technical skills and revive procedural knowledge during short courses on high fidelity simulators. Non-technical competencies and team skills (Flin et al., 2003) are minimally covered and implicitly left to mature from the practice of technical competencies over a range of simulated EAS scenarios.

Technology-centered approaches offer all-encompassing solutions in a constant struggle to eradicate or contain many sources of vulnerability. Information technology enables ATC units to be equipped with high fidelity simulators that simulate almost every technical aspect of the controller’s working position, including the logic of automation aids and safety nets. In this sense, simulators guide regulatory compliant training and drive an artificial need for more “featurism” in synthetic task environments. The choice of scenarios reflects those preferred by the overarching authorities (see ICAO, 2007) whose preferences remain far from questioning. Formal mechanisms of safety auditing (e.g., Safety Management Systems) serve only to check the compliance of training curricula to guidelines developed by International, national Civil Aviation Authorities and the units’ parent organizations. However, an alarming number of recent incidents and accidents in aviation indicated that effective handling of abnormal events requires more than technical competencies (Kirwan et al, 2005). Furthermore, studies of abnormal events in envisioned worlds discovered several hard-to-resolve decision tradeoffs that call
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for cooperative human-system architectures (Dekker, 1996; Dekker & Woods, 1999). It is very challenging, therefore, to specify training procedures resilient in the face of real world ambiguities, workload demands, and time constraints.

Overall, aviation refresher training appears to offer practice of skills out of the context of real-life work while the technical and human factors aspects of flight management seem fragmented. The training emphasis on technical competencies may reflect a dominant safety paradigm in aviation that operations can entirely be specified through operating procedures that should be faithfully followed by crews. The critical need for shifting to new training approaches with emphasis on non-textbook critical situations can be addressed using Resilience Engineering concepts. Resilience represents the ability of a system to adapt or absorb disturbances, disruptions and changes and especially those that fall outside the textbook operation envelope (Woods et al, 2007). EAS represent critical situations close to the margins of safe operation that challenge controllers’ operational practices and supervisory systems. The joint human and technical system is stretched to accommodate new demands and this offers opportunities for studying aspects of system resilience. A Resilience Engineering approach should address the affordances of the system, the controller strategies and their patterns of coordination. This triad of affordances, resilience strategies and coordination has been applied in a filed study of an ATC system. In line with this reasoning the aim of the study presented in this paper was threefold. Firstly to record cognitive strategies utilised in the tasks of experienced controllers in handling of EAS. Secondly, to propose a CTA method for studying how cognitive strategies emerge in a complex domain and how they can be used in the design of refresher training. The third and final aim was to provide a validated answer as to the adequacy of the refresher training to meet the challenges of EAS.

METHOD

The research method was based on observations and ratings of human performance in simulator-training scenarios for operational controllers combined with participation in Team Resource Management (TRM) courses in the context of the annual refresher training. This method of identifying cognitive strategies and rating their quality was preferred to the mere analysis of incident and accident reports that focus on technical aspects and operational errors. Observational data were combined with qualitative data from briefing and debriefing simulator sessions, focused interviews with controllers and instructors, and finally an analysis of key operational documents and training curricula. These research techniques belong to the “experiments in the field” family.
of methods and are based on scaled world simulations that capture critical aspects of the targeted situations (Woods & Hollnagel, 2006). A total of 21 dyadic teams of area controllers participated in the study while attending their annual refresher training as part of their competency scheme. During the TRM course, the instructors presented a number of incidents and the controllers had vivid discussions with regard to the operational strategies adopted and the role of the context of work. A set of 14 ATC incidents were analyzed, involving discussions with experienced controllers and instructors. The analysis of incidents formed a unique opportunity for listening to how operational controllers think about them.

Our research setting was a busy European Area Control Centre where operating teams comprised two controllers. The Executive Controller (EC) was responsible for the direct control of aircraft in the sector (i.e. area of responsibility) and for carrying out the overall plan. The Coordinating Controller (CC) was responsible for establishing the overall plan for the entry and exit of aircraft in the sector and for assisting EC in his/her tasks. Controllers manage air traffic in their sector by issuing arrays of complex instructions, clearances and information to flight crews. Radar is the primary sensor of the external environment (i.e. the sector and the surrounding airspace) and the main planning instrument for tactical handling of air traffic. An assortment of automated data-processing systems depicts the location of aircraft on the radar screen and enables a variety of supporting functions (e.g. Flight Data Processing).

The very essence of the area controller’s task is to detect and resolve potential separation losses between aircraft in order to prevent mid-air collisions. Technically, a loss of separation is a situation where the horizontal and vertical distance between two aircraft fall below prescribed thresholds. In our research setting, the nominal separation minima between aircrafts were 5Nm horizontally and 1000ft vertically. A loss of separation can be visualized as the overlapping of the protected airspaces of two aircraft (i.e. virtual cylinders around an aircraft with 2.5Nm radius and 1000ft height) while the overlap geometry determines the classification of severity.

T^EAM MODEL

In the first stage of the study, an inventory of cognitive strategies was compiled based on a literature review from the Naturalistic Decision Making and Cognitive Systems Engineering paradigms. Four prominent sources of references were used for the individual cognitive strategies. The Recognition Primed Decision (RPD) decision-making model (Klein, 1998), the Recognition/Meta-Recognition (R/M) decision-making model
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(Cohen et al, 1996) and the Contingent Operator Stress Model (COSMO) decision-making model (Kontogiannis, 1999). The fourth was a model of anomaly response as a multi-threaded process (Woods & Hollnagel, 2006). These models were selected based on the importance of the cognitive strategies they integrate and the consistency of the research paradigm with the field study requirements.

For the identification of patterns of joint cognitive performance, a compilation was made of four well-established frameworks from the same research paradigms. The first one was the Anaesthetists’ Non-Technical Skills, (ANTS) which is a validated and widely accepted framework (Fletcher et al, 2004). The Big Five, (Salas et al, 2005) is a teamwork model that has been developed by a critical review of empirical studies and theoretical models of teamwork, team effectiveness and team performance over the last decades. NOTECHS (Non Technical Skills) investigated possible ways to evaluate non-technical skills of multi pilot aircrew (Flin et al, 2003). The fourth model is a taxonomy of breakdowns in shared cognition (Wilson et al, 2007).

The first stage of the study resulted in a performance model, termed as Taskwork & Teamwork strategies in Emergencies in Air Traffic Management (see T²EAM in Malakis et al, in Press –a, b). T²EAM model (Table 1) is an attempt for a balanced and pragmatic approach to capture resilient processes during EAS episodes in the ATC system.

<table>
<thead>
<tr>
<th>Individual Strategies</th>
<th>Teamwork Strategies</th>
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<tr>
<td>Recognition (i.e., noticing cues, recognizing states and projecting future states)</td>
<td>Team orientation (i.e., shared situation understanding and communication of intent)</td>
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<tr>
<td>Managing uncertainty (i.e., critiquing goals and mental models)</td>
<td>Team coordination (i.e., managing dependencies and avoiding information garbling)</td>
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<tr>
<td>Anticipation (i.e., acknowledging threats and exploiting less busy periods to plan)</td>
<td>Team communication (i.e., providing unsolicited information and updating situation status)</td>
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<td>Planning for typical events and contingencies</td>
<td>Error management (i.e., error detection and correction)</td>
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<tr>
<td>Managing workload (i.e., prioritizing tasks and coping with interruptions and distractions)</td>
<td>Change management (i.e., detecting and correcting problems in distribution of tasks)</td>
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Table 1: T²EAM Model
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For the rating of controllers’ performance, we used a 7-point behaviourally-anchored scale as it was thought to give a good rating sensitivity to subject matter expert observers. The collected data were submitted to a Principal Component Analysis to establish the construct validity by revealing factor solutions that corresponded to the hypothesized models of individual and cognitive performance. The metrics of cognitive strategies were illustrated with good and poor exemplars (i.e., behavioural markers). This refinement of cognitive strategies was based on interviews with controllers and instructors so that they were able to apply this method on their own and achieve consensus in their judgement. An inter-rater validity study is currently in progress to test the screening cognitive strategy tool and promote greater use within the ATC environment.

RESULTS

As it was naturally expected in the refresher course, controllers excelled in all cognitive strategies and especially, recognition, anticipation and planning. Successful performance could be attributed mainly to the familiarisation training and the experience of controllers. Controllers were briefed about the EAS types and knew what cues to look for. They also knew how the situation could evolve over time, and how to respond to the situation. Sheer amount of operational experience, combined with intensive training, resulted in excelling controller performance. High performance scores were also achieved in managing workload and uncertainty although the practiced scenarios were not rated highly in terms of their demand for such strategies.

Regarding teamwork, all strategies received high scores and especially information exchange and team coordination. Expert controllers, for instance, could communicate effectively without unnecessary queries that prolong and garble communication. They were able to appreciate major attributes of information (i.e. criticality and timelines) and judge the level of workload and interruptibility of other members; as a result, the EC was not distracted by the CC with non-critical information in critical phases of the situation. This success in coordination, however, provided few opportunities for practising error recovery and task change management since the controllers committed few errors. Only two cases of separation loss were recorded in refresher training, both occurring in the ‘emergency descend’ scenario.

With regard to real incidents in the TRM course, a different picture emerged as controllers made some errors in recognizing problems, anticipating threats and planning the traffic. In the real operating environment, some errors seem unavoidable especially...
Is refresher training of air traffic controllers adequate to meet the challenges of emergencies and abnormal situations when working under heavy workload and the influence of interruptions and distractions. It is the ability of the expert controllers to manage these errors and change their response that can contain any adverse system consequences and eventually “engineer” resilience into the system. The result of the analysis of the TRM incidents, however, indicated that loss of separation was the result of failures in error management and task distribution. Firstly, CC did not detect timely the imminent separation loss and did not provide feedback for error correction to the EC. Secondly, the performance of the EC in the recovery phase was less than adequate. The EC seemed to be surprised by what was happening and lost precious time in issuing questions to the pilot crews about their actions; even when the EC reacted, his/her interventions were not adequate to resolve quickly the situation but rather prolonged the conflict.

T²EAM MODEL AND COGNITIVE TASK ANALYSIS

In the second stage, the T²EAM model formed the basis for the development of a Cognitive Task Analysis (CTA) method by grouping cognitive strategies into three categories of performance patterns. Abstracting generic performance patterns, recurring over many variations in a particular domain, are one of the core activities of the Cognitive Systems Engineering paradigm (Woods & Hollnagel, 2006). A pattern can be described as a relational property that captures problems and opportunities arising at the intersection of sharp-end practitioners, situational demands and artefacts. The complexity of controlling a process calls for elaborate strategies of adaptation of the human-system ensemble. Three types of patterns characterize the degree of adaptation at work: Coordination (between practitioners), Resilience (between practitioners and demands) and Affordances (between practitioners and artifacts). On the contrary, under-adaptation is characterized by their opposites: Miscoordination, Brittleness and Clumsiness. A description of generic patterns offers a good basis for the analysis of EAS demands and the analysis of cognitive strategies employed by front-end practitioners.

The T²EAM model can be used to investigate the demands of many EAS scenarios and the cognitive strategies employed by expert controllers. For example, in the ‘diversion’ scenario an aircraft experiences a malfunction and must be re-routed to another airport different from its final destination. Challenging decisions include, managing uncertainty to recognize problems, anticipating threats, standard planning, and contingency planning. Observation of expert controllers revealed that these cognitive strategies emerged in a fluid and flexible manner and shifted in response to the dynamic
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The incident starts when an aircraft experiences a malfunction and request the meteorological conditions (METAR) of a nearby airport. Although not alerted by the flight crew, the controllers become suspicious of a potential threat and prepare their colleagues in other ATC sectors that supervise possible diversion airports. They also make all necessary coordination for reserving a military airspace that blocks direct access to the diversion airport. Most of the activities are part of the controller strategies for managing uncertainty and planning for contingencies. They avoided asking any questions to the flight crew to let them concentrate on the potential threat and wait until the flight crews declared an emergency. With their planning-ahead strategy, the controllers were able to resolve any potential traffic conflicts and routed the aircraft safely to a diversion airport. This scenario presented controllers with a mix of delayed cues (e.g., delayed declaration of emergency) masked cues (e.g., crew request of the weather of a nearby airport) and attention diverting cues (e.g., other aircraft on the radar screen). To cope with these demands, controllers recognized the uncertainty of the situation, anticipated possible threats, and planned for a few contingent events (e.g., diversion to an airport and reservation of the military airspace). A smooth pattern of coordination was also observed where controllers made all the necessary arrangements without garbling the flight crew and the adjacent sectors with unnecessary information.

CONCLUSION

Instructional methods, such as training needs analysis, cognitive task analysis, scenario design, performance measurements and feedback or debriefing, are necessary to ensure mastery and evaluation of emergency response skills. Despite the earlier suggestions that aviation training should follow a systematic approach, the present study found that this systematic approach has not been applied to the refresher training in air traffic control. Training needs analysis should be guided by CTA methods in order to specify the cognitive and team strategies that will become the focus of the training curriculum. The taxonomy of cognitive strategies specified in T’EAM provide a good basis for conducting CTA and specify the cues, the challenges, the decisions, and the strategies used by experienced controllers in the course of events of a complex scenario.

The proposed CTA can also help instructor to enhance the ‘cognitive fidelity’ of training by identifying events in a scenario that would provide opportunities to controllers to practice specific cognitive strategies. Some strategies may occur
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Infrequently or may be difficult to observe for an instructor (e.g., managing uncertainty) and should be provoked or triggered by specific events (e.g., withholding information from the controllers). The cognitive strategies of T²EAM can also provide input to the Event Based Approach to Training (EBAT) approach for the acquisition and refreshing of skills required in ATC emergencies.

The examination of the refresher-training course is an initial step in tailoring the training requirements to operational reality. Additional research is needed to reproduce the tentative findings presented here and derive a more informative framework of cognitive strategies. Although field studies impose, several limitations related to controllability, their findings have high face validity in the practitioners. The present findings can help ATC organizations to diagnose weakness in their training and seek advice in overcoming them. The cognitive strategies can provide the foundation of an advanced safety-training course, complementary to the existing refresher course aimed at cultivating resilience.

REFERENCES


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