AVIATION
2008
12(1): 22–27

PILOT TRAINING IN OUR TIME – USE OF FLIGHT TRAINING DEVICES AND SIMULATORS

Nicklas Dahlström

Lund University School of Aviation, Drottningvagen 5, 260 70 Ljungbyhed, Sweden
E-mail: nicklas.dahlstrom@tfhs.lu.se

Received 20 August 2007, accepted 28 February 2008

Nicklas DAHLSTRÖM, PhD
Education: PhD in the field of Human Factors in Aviation, 2007, Lund Institute of Technology; Air Force Meteorologist (officer's education in combination with BSc below), 1993; Bachelor of Science in physics and meteorology, 1993, Stockholm University.
Professional activity: researcher and instructor in Human Factors and CRM, 2001, Lund University School of Aviation. Ground Instructor in Human Performance and Limitations and CRM, 1998, Lund University School of Aviation Air Force Meteorologist, 1993, Swedish Air Force.

Abstract. The challenge of pilot training include adapting to an industry in which the environment is formed by steep upturns and downturns, cut-throat competition, and advanced technology that continues to change the role of the pilot and in which safety always must match the continuously increasing demands of efficiency. The pilot training performed at flight training organisations (FTOs) is the fundament in the education of captains and first officers who will be able to manage the operational "sharp end" of this environment.
The response from the training industry in adapting to this environment has to a large extent been to increasingly rely on various levels of simulation in training, as seen with the current introduction of the multi-crew pilot license (MPL). Simulation can play an important role in acquiring the skills needed for a pilot, but it is also necessary to focus on the cognitive and collaborative skills that are to be developed by the training. The increasing technological sophistication seen in flight training devices and simulators today does however not seem to be matched by systematic validation of the value of different levels of simulation on cognitive and collaborative skills, which means that educational resources can go underutilised or get misapplied.
This paper will describe and discuss some aspects of the challenge for pilot training, especially regarding the use of flight training devices and simulators. The framework within which FTOs exist and perform their training will be presented to add context to the overall situation for pilot training. And in particular, recent Lund University School of Aviation research projects on pilot training, introduction of technically advanced aircraft (TAA), and use of mid-fidelity simulation for CRM-training will be presented and connected to the discussion.

Keywords: aviation safety, aviation human factors, flight simulation, flight training devices, pilot training, multi-crew pilot license.

1. Introduction

Accidents in aviation (as well as in other industries), such as Air Ontario at Dryden and British Midlands at Kegworth, have emphasized the importance of human factors in general and of information sharing, crew cooperation, and effective group decision making in particular. These accidents have also emphasized the role of command and previous training of these "general" competencies as part of the management of a situation in which events develop in a way that leads to an escalation of pressure on the crew [6]. Since investigations of this type of accidents frequently have identified poor training of the crew as a key contributing factor, the development and validation of training that improves the management of escalating situations should be of great importance in

ISSN1648-7788 print / ISSN 1822-4180 online
http://www.aviation.vgtu.lt; www.epnet.com; www.csa.com

making progress on safety [13]. This goes especially for situations that take crews outside of their routine work (i.e. beyond rules, standard operational procedures, and manuals). These situations are also typical for when crew encounter new technology in the work environment, such as when complex automation was introduced in airliners [3].

Research results from fire fighting tell us that successful management of escalating and complex situations relies heavily on the cognitive skills of the individuals involved as well as the teamwork skills of the group [10]. Among the cognitive processes that play an important role here are information processing, judgement, and decision making, and among the teamwork skills are communication, group interaction, and leadership [5,12]. Despite their criticality, opportunities to practise these skills are often limited. The continuous development of the capabilities of high-fidelity simulation has greatly improved the return on training investment with respect to technical handling of aircraft. Normal handling of aircraft as well as execution of standardised emergency routines can now be trained effectively in modern simulators. Modern technology in cockpits, (such as that posed by introducing TAAs in ab initio training) which in turn present new opportunities for errors and routes to breakdown, can also be introduced and practised with advanced high-fidelity simulators [11].

The development of high-fidelity simulation has not necessarily brought with it-improved opportunities for learning cognitive and coordinative skills, however. It is questionable whether there is an empirical basis for assessing the value of various levels of fidelity of aircraft or ship-bridge simulation on the teaching of these kinds of skills. The demand for continually increasing levels of high-fidelity simulation could be viewed as a response to the need to practise skills other than those of handling an aircraft. Despite the convincing visual effects, operator acceptance, and apparent validity of high-fidelity simulation, there is no certainty whether or to what extent quality of training is improved or better transferred to the operational environment by higher levels of fidelity.

There are indications that the transfer of cognitive and procedural training to practice may in fact benefit from lower-fidelity simulations, as this removes "distracting" featurism from the training setting [8]. This is indicated by Caird [1]:

> "…there is some evidence from flight simulation that higher levels of fidelity have little or no effect on skill transfer and reductions in fidelity actually improve training. Reductions of complexity may aid working memory and attention as skills and knowledge are initially acquired… Perhaps errors on the side of more fidelity reflect failed attempts to completely understand the underlying physical to cognitive mappings."

The connection between different levels of fidelity in training and different levels of learning seems to be underinvestigated and based mostly on a general faith in the effects of high fidelity. Caird stated "for decades, the naïve but persistent theory of fidelity has guided the fit of simulation systems to training" [1].

Strohschneider and Gerdes have shown that mid-fidelity simulations hold the potential of being very effective in teaching the cognitive and team skills necessary for the successful management of emergencies [12]. The tool used in this research was a mid-fidelity simulation of a ship, the M/S Antwerpen. The M/S Antwerpen simulation has previously been used in Germany for training of emergency management with hospital staff, fire fighters, and policemen.

Beginning in the eighties, progress in technology led to an increased use of advanced and complex technology in transport aircraft. The consequences of this on the work performed in the cockpit were initially overlooked, however. As new types of accidents started to occur, research of human factors tried to catch up to understand the origins of these accidents. While the industry believed that replacing tasks performed by pilots with automatic functions would not be problematic, this proved not to be true [4]. On the contrary, it has been proven that changing the tools that are used for work fundamentally changes the content of work.

During the last decade, the arrival of small aircraft, technically advanced aircraft (TAA), containing the same advanced and complex technology found in modern transport aircraft, has prompted similar questions as those asked when the paradigm of work in transport aircraft cockpits was changed. To what extent this will or should affect regulations for training, design of training, and learning processes of students has still not been investigated in depth. As seen earlier, the introduction of new technology is normally ahead of reflection on the potential consequences of the technology. Since Lund University School of Aviation in 2004 decided to renew its aircraft fleet, replacing traditional aircraft with TAAs, it was also decided that this process would be monitored by a research project to study activities before and during the introduction and in particular expected and unexpected problems encountered during the introduction.

2. Methods

2.1. Introduction of TAA study

The methodological approach in this study was to monitor the whole process of introduction, up to the first solo of the students, primarily by using interviews and questionnaires. Initially, the three flight instructors with responsibility for preparing the introduction were interviewed regarding the preparations for and their expectations about the introduction. The next step was to design questionnaires to be used, for flight instructors after their familiarisation flights with the aircraft and for students and flight instructors after selected flights up to the first solo. The questionnaires were based on bipolar questions regarding mental workload, learning, and use of the new technology in the aircraft. The same type of questionnaires that were used here had been tested in previous studies at Lund University School of Aviation [10, 14]. Out of the 18 flights leading up to the first solo, three flights were selected as suitable for data collection. These flights were spaced to ensure accumulation of experience of the students without recently having added too much new content to the training. Finally, another set of interviews with three flight instructors on the course were performed. These were performed to be able to reflect on some of the data collected from student flights and to provide an overall view of the introduction process.

2.2. M/S Antwerpen study

Of a total of 31 participants, 27 were students at Lund University School of Aviation in the later stage of their 20-month-long training in the Airline Transport Pilot Program and four were students in the Flight Instructor Program. The M/S Antwerpen simulation was performed in groups of six students, except in one case in which the flight instructor students participated and there were seven students in the group. The age of the participants ranged from 21 to 30.

The M/S Antwerpen simulation represents a new type of mid-fidelity simulation that seems to be rarely used in crew training. It is a complex simulation that includes all the major technical aspects of a cruising ship as well as other conditions like sea, weather, and other traffic. The task given to the participants is to safely navigate the ship M/S Antwerpen through a stormy night in the Atlantic Ocean. Due to adverse conditions and the age of the ship, the crew needs to deal with different types of problems that in the end may result in a state of emergency. The participants play designed roles as captain, first officer, first engineer, chief steward, ship's doctor, navigation officer, and first machinist. The simulation program is run by two facilitators and most of the communication with the participants is provided by printouts that feed standard information and information about anything that would be outside of the normal and safe operation of the ship. The participants have complete control of the ship and have to develop among themselves both overall strategies and instantaneous solutions to the situations that arise during the ship's voyage.

The M/S Antwerpen simulation is in it a part of a training program designed to develop the cognitive and cooperative skills of a group. The two-day program starts with an introduction and then continues with instructions, followed by the start of the first trip with the ship. This scenario is rarely completed entirely successfully by a group and is followed by a debriefing session. After this, lectures and discussions on effective group behaviour, especially related to emergency management, follow. The second scenario is designed to be more likely to end successfully and is also followed by a debriefing session. Data from the two trips with the M/S Antwerpen with each group was collected in the form of log files from the simulation itself, the collection of all order-notes given from the participants to the facilitators, and observations of the group made by a designated observer. The data from the sessions with the M/S Antwerpen have not yet been systematically analysed, and all results presented in this paper should be considered preliminary since they are based predominantly on observations made during the sessions.

The tasks that a group has to solve during the M/S Antwerpen vary from trivial to avoidance of disaster, and it is not designed to be used in a maritime setting. Even though the high level of detail in the simulation certainly makes this use highly relevant, this was not the original intention with the simulation. Instead the intention is to practice individual and group skills regarding information management and decision-making. These skills are also central to crew resource management (CRM) as described by regulations and performed in the aviation industry today. In addition, it has long been proved that the principles of aviation CRM seem to be universal to safety-critical industries, and the aviation, maritime, nuclear and chemical industries, as well as health care, have developed and shared knowledge together for many years now.

3. Results

3.1. Introduction of TAA study

The results of the introduction of TAAs showed that initial problems expected by the flight instructors who planned and performed the first phase of the introduction were experienced by some of the students and instructors, but for the majority there were few or no problems in adapting to the new technological and procedural environment. The three main areas in which problems were expected were the use of new instrumentation (computer screens generating larger amounts of information and presenting it differently than on traditional instruments), the higher speed range of the aircraft (compared to the aircraft previously used for training) and the use of side control (instead of the traditionally centrally placed control stick). Initially, some problems were encountered with the new instrumentation, primarily with the amount of information available and with finding the right information. However, these problems seemed to be overcome by the time for the first solo flight. The higher speed range and the use of side control did not seem not to generate more than occasional problems, even in the early stages of the training.

The unproblematic introduction was attributed by flight instructors to the time and resources that had gone into planning and preparation of the training sessions and training material. It was considered particularly important that a group of six flight instructors were designated and given time to prepare for the course. The instructors quickly became well coordinated and calibrated, providing confidence to the instructors and avoiding the otherwise common frustrations of students experiencing different training with different instructors. Interestingly, some experiences expressed by the instructors after the first solo, such as excessive focus on instruments, lack of knowledge of technical systems (particularly regarding fuel planning and management), and a student engaging the flight automation and then being unable to disengage it, gave indications about the importance on continued monitoring of the introduction of the aircraft in subsequent phases of the training.

3.2. M/S Antwerpen study

Initially, the groups of participants were provided with general information about the M/S Antwerpen, the trip they were about to make, and their respective roles. Already at this stage the groups experienced problems with handling the amount of information they were provided with in the limited time available for preparation. Although this is part of the design of the training, the early phase of the first trip is relatively non-eventful and does provide time for the group to continue to sort out which information is available in the group. However, as the first trip started and information started to come out of the printer, the groups immediately became intensively engaged in the simulation. There were few attempts after this to regain an overview of the knowledge available in the group or on the structure of work in the groups. Attention was normally focused on the next sheet of paper coming out of the printer.

In none of the groups were goals or main priorities of the mission explicitly stated or even openly discussed during the first session. There were few or no attempts to form a strategy for information sharing, division of responsibilities (beyond those explicitly stated for the role), or how decisions should be made. The few attempts that were made were restricted to changing seats when realising that some roles had more in common than others and individual attempts by some participants to log their own activities or those transpiring in their department (primarily engineers logging maintenance and repair work on the technical systems of the ship). As the first session went along, those with less intensity followed more intensive periods. This provided groups with the opportunity to reflect on what had occurred on the ship and how the events had been managed. It was also is an opportunity to consider on a more general level how the work in the group was being performed and how it could be improved. These periods of idle time were however not used for any of this type of "process discussion". When the intensity went down the participants normally relaxed, chatted lightly about private matters, told some jokes, or simply sat, seemingly passive waiting for something to happen.

All of the groups participated lively, intensively and engagingly in the simulation. However, many of the discussions never came to any conclusion since they were interrupted by new information from the printer and many proposals accordingly never turned into action. In the absence of clear strategies regarding decision making, all crewmembers seemed to be empowered to make their own decisions. Initial attempts to have someone read and distribute information and to make sure that the captain was aware of all decisions were not stable in the face of the escalating intensity of the simulation. In every group there were examples of the same order coming from more than one crewmember, the crew not being aware of orders already having been given, and contradictory orders being provided to the facilitators. The lack of systematic information sharing and the consequences of it became obvious in the last stages of the first trip. When the scenario escalated and placed increasing levels of pressure on the crew, there were many signs of confusion in the groups, with the most obvious being that in some cases some participants were not even aware of the dangers threatening until late events had started. As the session entered its final stages, signs of the increasing pressure on the crew could also be observed as communication between crewmembers became increasingly difficult and could no longer sustain coordinated actions in the group. Orders became more unclear and difficult to interpret and seemed to be given without coordination from individuals or sub-groups within the group. For all of the groups, the first trip ended with loss of the ship and a majority of the passengers as fatal victims of the events.

In preparation for the second trip with the M/S Antwerpen all of the five groups acted decidedly more proactive than before the first trip; goals were explicitly formulated, roles and duties and information connected to them were clarified, orders for various expected situations were prepared, and different emergency scenarios were also discussed and prepared for. In addition, all of the groups had organised their seating and information in log-files and on desks, a whiteboard, and walls to facilitate their tasks. Briefing routines had been decided on by all of the groups. As the escalation of events in the scenario increased, individual group members seemed to be caught up in their own responsibilities and the emergence of yet another paper from the printer seemed to distract group members during the briefings. Even groups that with great engagement tried to maintain briefing discipline had problems, and after about half the session the briefings of all groups had lost their initial form and purpose.

More decisions were made in the second scenario and they were overall better coordinated than they were during the first scenario. The dramatic change in how information was managed in the group (from piles of paper on a table to data on a whiteboard, maps on the wall, log-files, etc.) and the briefings seemed to keep the groups together, which led to more effective use of the skills and resources available to the group. Even as the groups in the second session were more prepared and motivated by the opportunity to improve their performance, there was great variation among the groups in the use of idle time. While some of the groups did use idle time to review actions and take proactive measures against anticipated risks, others again fell back to more relaxed behaviour. The difficulties with getting caught up in the unfolding of events were proven by the variation in process-oriented discussions. While discussion of how the work was being done was present in some of the groups, it was still limited and for some groups there was practically no process discussion during the second scenario. The final results, as counted in fatal victims of events on the ship, of the groups did not necessarily mirror the improvements in performance, but in the debriefing sessions after the second trip all groups expressed satisfaction with the improvement in their methods of managing the events. Also, all groups stated that they found the sessions to be important for their future role as airline pilots.

4. Discussion

4.1. Introduction of TAA study

The results of the study of the introduction of TAAs in ab initio flight training did show that this could be accomplished successfully. Few of the concerns that surfaced during the preparation for the introduction translated into problems for the students; not even the first flight resulted in a majority of students experiencing the anticipated problems. Regarding the time and resources used to prepare and follow up on the introduction as the reason for the successful introduction, as expressed by flight instructors, seems relevant. While new technology often promises increased system capabilities (for training: same as before, but now simpler and better) and safety, it also transforms the work of an operator and creates new ways for breakdown of performance and possibilities for new forms of accidents [4]. Consequently, the implications for the introduction of TAAs in basic aviation training were that only minimal preparations should be necessary. The Federal Aviation Administration has concluded, however, that to achieve the potential for increased safety available with TAAs additional training on specific TAA systems is necessary [6]. Time and resources utilised in the introduction of TAAs in this particular flight-training organisation seem to have facilitated the transformation of work and made it possible to avoid the initial pitfalls of the shift in technology. However, further research on the expected positive outcomes and potential problems of introducing TAAs is required; use of automation, transfer from the modern environment of a TAA to a traditional cockpit (still often found in commercial aviation), and the potential for acceptance of greater risk due to features intended for increased protection and safety need to be investigated. Also, the potential for loss of training qualities present in training with traditional aircraft should be investigated.

Comments on students being overly focused on the instruments and lacking in technical knowledge can be interpreted as indications that readily available information typical of the TAA cockpit shortcut or truncate active information management; the student knows how to work the system, but not how it works. To address these issues is of great importance to ensure that the expected benefits of using TAAs for basic aviation training translate into increased pilot competence, without the loss of cognitive skills needed for later stages of one's career. (The full articles on this project has recently been published in the International Journal of Applied Aviation Studies, see reference list) [2].

4.2. M/S Antwerpen study

The results of the M/S Antwerpen indicates the usefulness of mid-fidelity simulation for training of generalised skills such as information sharing, group interaction, and decision making. The observations made during the sessions also provide interesting insights into individual and group actions in an escalating situation and proves that the M/S Antwerpen can be used as a research tool to investigate individual and group processes in action in these types of scenarios. In particular the participant acceptance, and appreciation of the value of M/S Antwerpen as a training tool questions the need for the type of "photo realism" required in aviation today by regulations, provided by simulator manufacturers, and favoured by operators themselves. In light of the removal of the opportunity to focus on instrument readings and control settings, the participants in the M/S Antwerpen sessions are put in a situation in which their most useful tools are those of understanding the behaviour of themselves and their group.

Although the effects of the improvements in information management in the groups could be argued to be unsurprising (since it is one of the main learning points after the first session), the lack of structure in information management in all of the groups was still surprising. In spite of confusion, lack of knowledge, and uncoordinated and contradictory orders, there were few or no attempts during the first sessions to discuss or change the way information was managed. The dominance of the issues at hand at that moment seemed to effectively block any attempts to consider other strategies for handling information in the group. The process-oriented discussions yielded another interesting observation. The lack of this even during the second scenario can be interpreted as a strong indicator of the difficulties for a group to break out of the minute-to-minute management of events and instead focus on how the work is being done and consider whether it can be organised more effectively. This seems to be a quality of group management of escalating situations that needs a considerable amount of training before it can be applied in situations of increasing stress.

The M/S Antwerpen has also provided the observers of the processes in the groups with questions of generalised and specialised competence. In most operator professions, training starts with performing the specific operation, although with simple and restricted tasks. The student operator then continues to develop operational competence in parallel with acquiring knowledge deemed necessary for the operation. This creates a track to the future work role in which generalised competence, such as that of decision-making and group interaction is interwoven with the practise of skills in the operational frame. In other professions (such as engineering, medicine etc.), generalised competence is the starting point of the building of professional skills. Only later in the education and training do specific procedures for performance and professional action become a part of the skills. How these different routes to competence that needs to be used under high stress might affect analysis and action in escalating situations is a question that will be considered in the further use of the M/S Antwerpen.

5. Conclusions

From the TAA study a conclusion in regards to basic civil aviation training is that the introduction of trainer aircraft equipped with modern cockpit technology (i.e. TAA), in ab initio flight training can be accomplished successfully with early and extensive involvement of flight instructors in planning, preparation and mitigation of the impact this will have on the training.

However, in can also be concluded that student pilot understanding and operation of TAAs-specifically regarding manual flying skills, automation-related behaviour and risk-taking-indicate a need for further research on their use in ab initio training and its consequences for later stages of pilot training.

The M/S Antwerpen study has implications for simulation and training in a broader perspective. The main conclusion here is that to equate fidelity and domain or context specificity with better training is based on a limited and restricted view on training - deeper analysis of learning aspects needs to be more in focus than it previously has been in the aviation industry.

In addition the M/S Antwerpen study opens up for a complementary use of simulation in highly specific contexts since a conclusion from it is that training can be complemented with lower levels on simulation to train general competencies – in particular for unexpected and escalating situations.

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MOKOMŲJŲ SKRAIDYMO PRIETAISŲ BEI TRENIRUOKLIŲ NAUDOJIMAS ORLAIVIŲ PILOTŲ MOKYMUI ŠIAIS LAIKAIS

N. Dahlström

S a n t r a u k a

Šiame tyrime aptariama ir diskutuojama tam tikrais iššūkio bendrajam mokymui aspektais, ypač skrydžių mokymo prietaisų bei treniruoklių naudojimo klausimais. Supažindinama su egzistuojančių ir mokymą vykdančių SMO (skrydžių mokymo organizacijos) vidine struktūra, siekiant suprasti visaapimančio bendrojo mokymo situaciją. Įpatingas dėmesys skirtas Lundo universiteto pilotų mokyklai, kurios studentai dalyvauja aviacijos tyrimų projektuose; taip pat pristatoma techniškai pažangaus lėktuvo (TPL) įranga bei vidutinis tikrų sąlygų imitavimas pilotų mokyme.

Reikšminiai žodžiai: aviacinė sauga, žmogiškasis faktorius aviacijoje, skrydžio treniruoklis.