Learning how to escape the unthinkable with virtual reality: the case of pilots’ training on emergency procedures

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Abstract. The focus of this paper is the development of a digital escape room for pilots’ training in flight safety procedures. To this end, we will discuss the methodology we used in order to make sure that each stage of the evolution of our digital platform is safe and suitable for educational use. Therefore, we will analyse the first stages towards the construction and evaluation of the scenarios incorporated in our entirely digital escape room that is intended for the T-6A Texan II pilots’ education. Because of the educational character of the digital escape room, the theoretical background of our research is extremely important, since it provides the escape room with the educational aspect. As a result, for the narratives of our simulations and the development of our emergency cases, we used as our baseline the flight manual, the boldface procedures and the operating limitations of T-6A aircraft and we selected the categories of incidents/emergencies to be used as part of our virtual escape room. We, then, constructed the trial-run scenarios that we asked pilots to solve. Finally, we conducted extensive field research with the development and use of appropriate questionnaires and interviews to evaluate the realism of our scenarios. Based on the feedback we received from the field research, we will conclude this paper by discussing the limitations of this study, but also our ideas for future improvements and a timeline on our research progress, as well as on further developing our virtual escape room.

Keywords: Education and Training Programs, Safety Regulations, Virtual Reality, Digital Escape Room, Serious Games, Flight Safety, Hands-on-Training for Emergency Procedures

1. Introduction

Educating cadets on emergency procedures and flight safety [1] [2] is deemed a very important parameter of the flight training during all flight training stages [3]. Whether someone has just entered
the Academy and is going for his/her first flight or he/she is a third-year student with some prior flight training, the importance of following the protocols during any emergency situation is always and repetitively pointed out. Flight officers apart from enhancing the theoretical background with real flight hours, i.e. time spent in the sky on an aircraft, make use of the flight simulators [4] [5] that are available at the Air Training Wings. In relation to the flight simulators and their VR training goals and procedures, there is an existing bibliography that discusses the pros and cons of their use; there are different types of flight simulators [6] to cover a variety of training needs [7] [8] and their use is deemed an invaluable training asset [9]. But there is a catch to this: cadets can only use the flight simulator when a flight officer is with them [10]; if they want to practice alone, they just cannot do it. Also, if they want to test their knowledge, ability and preparedness to deal with a variety of critical cases and even rare real-life scenarios with different levels of difficulty, they cannot do it, unless they are on base with their supervisor. Given the limitations posed using a single flight simulator by many trainees, each trainee has a limited access to the simulator, especially during the winter months, when actual flights are limited because of the bad weather. It is also true that due to technical inspections and maintenance of the flight simulator, but also due to other unforeseen situations, as well as personnel leaves, the flight simulator on the base is not always available.

Therefore, we tried to figure out a way, so that cadets can get a virtual, but close-to-real and meaningful flight experience without the need of being supervised by a flight officer. Our proposed digital solution is more economical, since our platform needs no spare parts, machine maintenance, that can include regularly scheduled service, routine checks, and both scheduled and emergency repairs and, of course technicians’ wages, all of which cost money and time. That said, the focus of our paper is the development of a digital escape room for pilots’ training [11] in flight safety procedures; the idea of using escape rooms for training purposes [12] is an entirely different educational approach; a digital escape room has not, so far, been tested for flight safety training. To this end, we will analyze the first stages towards the construction and evaluation of the scenarios incorporated in our educational escape room for the pilots of the T-6A Texan II. To the best of our knowledge, there is no other entirely digital, educational platform that supports and enhances remotely pilots’ education on safety procedures and decision making for dealing with incidents during flight.

The first part of our research was carried out in two stages: (a) we studied the flight manual, the boldface procedures and the operating limitations of T-6A aircraft in order to write down the procedures set out to be followed in key incident categories (aircraft evacuation, regain control and landing) and (b) we selected the categories of incidents/emergencies to be used as part of our virtual escape room [electronic and mechanical malfunctions, multiple malfunctions (electronic and/or mechanical) immediately after take-off, during cruise and landing]; we also decided how to set up the difficulty level for each incident or emergency scenario and the time, which would be available to the pilots, so as to solve the case.

Subsequently, initially, we constructed the scenarios that pilots would be asked to solve; for this part of our research, we mainly teamed up as an interdisciplinary research group and got help to test our ideas from focus groups, which consisted of pilots with different levels of experience. In order to evaluate our scenarios, we did run various tests too: (a) in the cockpit of the aircraft, (b) in the cockpit of the flight simulator, c) on a recreational digital flight simulator that was not intended for educational use, so, we could only test a limited part of our emergencies, and (d) in the form of time-tested scripts to compare methods for efficiency learning the safety procedures and the relevant regulations of the aircraft. To fully test our emergencies and their narratives, we also developed and used questionnaires, as well as held interviews with both trainees (i.e., the players and our targeted population) and trainers to evaluate the realism of our scenarios.

The last stage of our research work was the development of the actual virtual escape room. Given the novelty of our educational approach (training pilots for emergency procedures not in a flight simulator, but through a completely digital educational escape room accessed remotely on and off base) and the fact that no other digital educational escape room for T-6A Texan II aircraft exists, a number of questions had to be answered, such as, whether: (a) we should develop an application (app) for
phones, construct an escape box or try to simulate the cockpit as best as possible, (b) we should make trainee pilots’ performance known to their instructors, (c) we should give the pilots’ the opportunity to collaborate or fly together, at least in some of the scenarios, (d) we should set up a virtual escape room, which will be part of the Wing’s training procedures or set up a virtual escape room, which will be used as an educational tool, but each pilot will decide, if he/she will make use of the virtual escape room or not. We will conclude our paper with comments about future improvements and a timeline on our research progress, as well as on potential further developments of our virtual escape room.

2. Proposed training methodology

When we come to think how to effectively prepare flight trainees involved in a potential crisis management in mid-air, the first thing that strikes our minds is to extensively train and educate them well and in depth, so those, who could find themselves in critical situations, to be able to understand and describe what is happening, and, also, to make decisions or act or both. Therefore, given the differences between a theoretical education and a realist training, the second point needs to be effectively addressed. One thing is certain: we need to prepare flight trainees before the crisis comes around. We need to start discussing the safety issues early, which is something that usually happens on the theoretical level during the first semester of study at the air force academies. However, is theoretical approach considered a successful mean of training on safety procedures? Apparently not, trainees definitely need to study the theoretical background, but they also need to practice on decision making and taking actions when there is no time to lose. Therefore, we need to provide flight trainees both with the theoretical background and the hands-on training, if we want them to be able to effectively deal with emergencies.

Given the aforementioned and the educational scope of our Academy, in order to evaluate cadets’ knowledge on flight safety and emergency procedures, we thought it is extremely important to plan, design and develop an interactive, Virtual Reality (VR) simulation for educational purposes, designed to be used by the trainees remotely and working on a merely digital form, so as to provide them with a virtual, real-time experience on dealing with critical situations related to flight safety. The idea is that they will thus have the opportunity to exercise their theoretical knowledge and realize by themselves the difficulties of handling difficult situations in mid-air. Also, they will be able to feel and understand what it means to consider different options and think about their actions in risky situations, when there is no time to lose.

The main difference between our VR game for educating flight trainees on flight safety and emergency procedures and our innovation is that it truly brings e-learning as an applied, digital element in flight training. Nowadays, the main educational approach to flight safety training is a mixture of providing theoretical knowledge in class and hand-on-training either by a real flight either with the use of a flight simulation [13] [14] under the strict rule that a flight officer needs to be with the trainee at all times. Real flight hours, however, are limited, especially for the initial flight training. This approach comes with obvious limitations.

**Solution 1.** Provide trainees with the theoretical background in class, then by the use of appropriate documentaries or educational films give them a view of a critical situation and, finally, by role-playing put them in the shoes of those who had to deal with a flight emergency.

**Limitation 1.** But while studying and analysing flight manuals, rules and safety regulations may help trainees to think of the appropriate action one should take in a critical situation, this educational approach cannot prepare trainees to deal with complex situation in limited real time while being under stress. This is because they learn and discuss various approaches to deal with emergencies, but mainly in theory. One needs a more systematic approach to handle real life emergencies effectively.

**Solution 2.** Discuss safety regulations before or after a real or simulated flight takes place during briefing or debriefing are also used in order to provide trainees with a useful framework, so as to reflect on emergencies in a more organized context.

**Limitation 2.** The applied approach is not missing, since a discussion and analysis of applied issues takes place and theory is combined with practice (even when the flight simulator is used). However,
trainees have no access to any educational or training tool that will help them practice when a flight officer is not available.

**Solution 3. Use of approved and tested scenarios with limited risk for the trainers and trainees involved during real or simulated flight to make trainees get the real feeling of an emergency situation.**

**Limitation 3. It is not advisable to put trainees in dangerous situations however limited the danger might be. In mid-air any additional unforeseen factor might put the flight in real danger.** As far as the flight simulator [15] [16] is concerned, this may be a better option [17] [18], but we should not forget that for the use of flight simulator, a flight officer always must be available. Therefore, trainees cannot even practice virtually as frequently as they would wish.

Games and simulations [19], on the other hand, allow us to cater for these aspects. In our virtual and completely digital cockpit everything will be put to the test: theoretical knowledge, different approaches, and hard choices. Trainees will also have the opportunity to remotely work together and test how they would cooperate in difficult situations. Flight officers, i.e. the trainers, will have access to the results that will show how the theoretical background and the level of knowledge affected trainees into making critical decisions; next time they enter the class or a briefing/debriefing session, they will know what needs to be further explained.

Our proposed method aims firstly to educate trainees on safety regulations from day 1 they enter the Academy. Secondly, to enhance the use of traditional techniques and role playing to teach the theoretical background. Thirdly, to use our interactive, educational and fully digital escape room to further test the theoretical background, but also to provide hands-on training by making trainees to put to test their knowledge, their ability for critical thinking and cooperation with other trainees (if the scenario has to do with flight in formation). Finally, to benefit from the mixed method of testing the theoretical knowledge per se, as well as its application in a virtual practice space (with no need for the presence of a flight officer for the simulation to take place).

The benefits of our proposed method will help flight officers to provide their trainees with well-rounded training. They can still use traditional techniques in order to provide an effective training (briefing/debriefing, analysis of flight emergencies, role playing etc.) as far as the theoretical background is concerned, but they will also be able to use our virtual escape room: a) to test the theoretical knowledge their trainees have, b) to check how stress and time limitations affect how knowledge is applied in practice and c) to provide their trainees with virtual hands-on training, and, the most complete possible education, in terms of theory and practice. Trainees will also get the best possible training, in terms of both theory and practice. They will also be able to test themselves individually whenever they feel like using our VR simulation on their personal computer (PC) or smartphone.

Trainees’ evaluation will be based on their choices, decisions and actions within the simulated emergency situation. At the end of the game, trainees will be presented with the list of options they made and how it rated against the different flight parameters that determined its payoff. Flight officers will be able to use the evaluation in a debriefing class after the game.

3. **Our scenarios**

The first step for our VR escape room was to develop emergency scenarios to virtually train cadets in a variety of situations of graduated difficulty with time constraints. In order to develop and test our scenarios we followed the following steps.

First of all, we paid particular importance to the Check List and the T-6A Techniques and Procedures Manual and, then, we used focus groups and interviews with the flight officers in order to test our scenarios and edit them or change any parameter that wasn’t right. Each scenario has a different level of difficulty and the time frame for the trainee to handle each critical situation is different, depending on the issues he/she has to face and the phase of the flight (e.g. limited time is available during take-off and landing for obvious reasons). One can see a short presentation of the parameters for each scenario in the following Table, starting from the most manageable one (Scenario 1) to the most difficult (Scenario 4).
Table 1. Levels of Difficulty to Different Scenarios.

| Scenario | Level of difficulty | Type of emergency | Parameters to exceed difficulty | Situation | Indications | Narratives |
|----------|---------------------|-------------------|----------------------------------|-----------|-------------|------------|
| 1        | I                   | Generator Failure | Weather, Distance from destination, configuration | Trainee exits from an unusual position with the head down. | Illumination GEN, MASTER WARN | After taking off trainee notices that GEN is still off (DC<25 Volts & AMMETER runs out of charge) |
| 2        | II                  | Smoke in the Cockpit | Weather, Distance from destination, configuration | Trainee exits from an unusual position with the head up. | Smoke in the cockpit and smell of plastic. | Smoke remains even after taking action. |
| 3        | III                 | Engine Stall/Failure | Altitude, Distance from destination | Manoeuvre: loop, shortly after the reverse. Loss of power, accompanied by a noticeable change in engine noise. | Gen. Fuel PX. OIL PX. OBOGS FAIL. PMU FAIL. CKTP PX. | Complete loss of power. Speed reduction. Lower N1, torque, ITT. Lower oil pressure. Lower propeller movement. Low fuel flow. Low hydraulic pressure. |
| 4        | IV                  | Low Hydraulic Pressure and Uncommanded Propeller Feather | Manoeuvre: take off | Loss of power. Lower Np. Increased torque. | Master Warn. PMU FAIL. CHIP. | During landing configuration, the following indications appear Master Caution & HYDR FL LO. |

4. Assessment of our proposed scenarios
After developing our scenarios, we asked from the flight officers to evaluate them by providing them questionnaires to answer and by giving interviews [20] [21]. We were particularly interested on the realism of our scenarios, the amount of time given to the trainees and the recommended steps to deal with each critical situation. Flight officers, who participated in our research, cover the 94% of the pilots’ population of the 120 Air Training Wing, which is located in the area of Kalamata. Their flight experience can be found in the following Table.

Table 2. Flight officers’ experience.

| Years after graduation from the Hellenic Air Force Academy | X≤10: 10%  
| 10≤X≤15: 35%  
| 15≤X: 55% |
| Total flight hours: | Average 2.200 |
| Flight hours on T-6A: | Average 1.700 |
| Flight hours on a different trainer aircraft: | Average 0 |
| Experience in education in relation to flight training | 16.6% |
| Place of interviews: | 120 Air Training Wing: 100% |
As far as the evaluation of the level of realism and difficulty of each scenario, the comments we received for our scenarios were overall positive (89%), because the problems posed demand both knowledge of the safety regulations and the aircraft’s T-6A manual, as well as critical thinking in order to be solved. Flight officers expressed the view that “trainees, in order to deal with an emergency situation, must be able to think and combine different parameters, such as manoeuvre, configuration, mechanical failures, weather”; our parameters and narratives made scenarios realistic enough to be part of flight training (82%). Also, the different parameters and their part in each scenario were deemed as rather important (92%). The level of difficulty made each scenario to be “appropriate for different phases of flight training” and the gradation of difficulty was deemed appropriate and well estimated (78%).

On the need to rewrite or edit any scenario in total or in any part of it in relation to the problem posed or its parameters, the majority of flight officers (84%) expressed the opinion that “gradation of difficulty was appropriate and well estimated”. The hypothetical scenarios and their story were also positive evaluated (76%). Some comments (8%) were related to specific parameters, i.e. airspeed, or the difficulty of our third scenario in which altitude and distance from destination made the situation extreme.

Flight officers were also positive (84%) about the educational aspect of each scenario. When asked whether our scenarios are good enough to be part of flight safety training, they replied that “each scenario is educationally interesting, and it has a realistic story for the trainees to solve” (tested positive for 88% of the targeted population). Our scenarios serve their educational purpose (92%), because they deal with several cases related to different phases of flight, therefore cadets can understand that emergencies of any type can come up anytime. However, we have been asked (8%) to include scenarios regarding formation flying and we also received a negative comment concerning scenario 4, which was deemed as “quite difficult and extreme/ unrealistic”. Nevertheless, the trainer, who gave us this comment, told us that it is a good scenario for the simulator and as a case study during debriefing.

The evaluation of our scenarios in relation to the scenarios already used as part of the flight simulator or the hypothetical scenarios that are used through debriefing to analyse possible critical situations came back also positive (92%). A general comment had to do with the fact that simulations and escape rooms might help cadets understand (even virtually) the realism of in-flight emergencies, but theoretical approach and study is necessary, and it cannot be substituted. Debriefing and analyzing case-studies (hypothetical or real) “can save lives, because it is a way of transmitting knowledge and experience”. Some trainers (24%) expressed the opinion that our virtual escape room should be remotely controlled by a trainer, who will set the parameters for each emergency and will also check the trainee’s approach to the problem posed. The general outcome was that “there is realism” in our scenarios and similar critical situations to our scenarios are also used in the flight simulator (86%). Finally, the fact that no one can access, influence and stop the evolution of any scenario running on the virtual escape room was deemed as very positive (88%). The trainee has to find the solution for himself/herself without the trainer’s help. This is not what happens with the flight simulator, since the trainer can stop the scenario running to discuss with the trainee any mistake during the educational procedure.

Our final question was whether the flight officers believe that virtual experience gained through our escape room will help trainees to better understand flight safety issues or the flight simulator already in use provides cadets with all the experience they need. Trainers said that the flight simulator covers some parameters of the virtual escape room (66%). However, “if the trainee has an application to test his/her knowledge anytime, this is always for the best” (28%). The fact that the results of the game can be viewed by the trainer and a debriefing can follow the virtual flight was deemed as an added bonus (92%), because this can help trainees to further understand the critical situation that needed to be dealt or their mistakes. One (1) out of three (3) trainers said that “new educational approaches through gaming would help cadets better understand the regulations and enhance the flight safety culture”.

5. Conclusions – Future work
From both our field research and interviews it appears that games, simulations and escape rooms are deemed necessary for trainees’ education and training on flight safety and emergency procedures. A virtual escape room with an educational focus, which can be remotely accessed and which runs in a full digital mode, as well as any new methodology of training on emergencies, would be helpful as a complimentary approach to study (theoretical approach), actually flying and using the flight simulation along with briefing and debriefing. But there are specific parameters that need to be in effect in order to make sure that the education purpose is served. On the digital platform, trainees should feel the amount of stress they would feel, if they had to deal with a real in-flight emergency. Therefore, time and sound warnings should be as realistic as possible.

In this paper, we have described the fundamental and crucial part of our current research: the development and testing of our scenarios. This means that, in the future, we need to reflect on the challenge, i.e. how we can introduce an educational method that will cover both the theoretical background, but also fully digitally and remotely provide with the much-needed training in realistic situations without compromising the safety of the flight trainees.

Our scenarios are part of an educational digital escape room. Those scenarios are part of a currently under development virtual simulation, accessed digitally through a platform, available for smartphones, tablets and/or PCs. Our goal is to further develop and use those scenarios for a completely virtual, digitally supported, experience, where trainees will have to use their knowledge of the aircraft and flight safety procedures, but also test their ability to critical examine flight parameters and prioritize their thoughts over the problem they face. We want to train them on how to come out of a dangerous situation, with no issues arising from any physical danger or potential harm to the trainees, who will play the game. Players will not have to enter any real aircraft or asked to perform any dangerous actions. Apart from the students’ physical safety, other issues have also been taken under consideration from our research team to ensure that there will be no issues related to students’ privacy (their evaluation will not be publicized, but will only be made known to them and to their flight officers, and, for this to happen, trainees, upon engaging in the simulation, will give their consent). In addition, we have to make sure that trainees will receive a valid, straightforward assessment of their choices, because otherwise they might be tempted to think that everything is relevant and even excusable in times of danger, which is not true. Scenario, storytelling, narratives and the visuals of the simulation must be evaluated and confirmed as educationally valid.

Therefore, the main objectives of our VR digital simulation on flight safety and emergency procedures are a) to facilitate the transition between theoretical education on the subjects of flight safety and emergency procedures to applied hands-on training, b) to provide trainees –through a simulated environment– with the analytic tools, in order to understand why safety rules and emergency procedures are mandatory and how to effectively use their knowledge to face possible critical situations that could arise during the flight, but, also, c) to make education and training on emergency procedures and flight safety, easily and remotely accessible to the trainees even from their room and when flight officers are not around. Consequently, the design of our VR simulation is based on real-life flight emergencies, and trainees need to study the theoretical framework before playing the game. At the end of the game and after their choices are evaluated, they will receive a full report of how they applied the relevant safety rules. This way they will fully understand the connection between theory and practice.

On the technical level, our scenarios support a fully digital simulation that can be played by one or multiple players, who will have the opportunity to fly alone or in formation. State of the art machine learning and artificial intelligence methods are developed and currently tested, in order to automate processes in the game play.

The first prototype of our virtual simulator will be out for testing and use during flight training on October 19, 2020 at 120 Air Training Wing of the Hellenic Air Force. More scenarios are prepared and are currently tested; they are further enhanced by additional reading and supporting bibliography that can be found at the end of each scenario. Also, some short tests follow each emergency scenario consisting of multiple choice questions, true or false (T/F) questions and multiple choice questions for the trainees to answer.
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