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# Virtual Reality (VR) and Augmented Reality (AR): a research study in new training opportunities in Aviation.

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***Abstract*:**
A new generation of learners, by some authors named the Next Generation of Aviation Professionals (NGAPs), are entering the aviation industry today. They are digital natives compared to digital immigrants and to engage and meet their needs, visualization of complicated, large data is helpful for understanding, analyzing and training. Although virtual and augmented reality (AR) are not new overlay digital content in our real-world environment and promises to transform the way we train NGAP to operate and maintain aircraft. This can provide a mobile cost-effective solution to enhance real-world environments, create virtual simulations, accelerate learning and increase retention. This paper firstly explores the technological issues involved in nowadays-digital culture and then it considers how pilots' training and aviation science lessons could be designed incorporating relevant and interactive software into a sound pedagogical strategy for aviation students and professionals. The "peep hole" approach allows focusing the attention of the pilot on critical issue even on full flight simulators on type conversion or periodical checks. This approach is particularly efficient in critical situation simulation and correction. The possibility to wear Head Worn Displays makes it possible to add virtual symbols to highlight positions and sequences. A careful choice of these symbols and highlights speeds up the learning process in a very significant way. This paper describes how to make it starting from Artificial Intelligence learning methods. This approach is particularly important when training takes place in full flight simulators where cost is high and time limited.

Keywords—Augmented Reality (AR); Full Flight Simulation; Mixed Reality (MR); Periodical Check, Training; Virtual Reality (VR)

## I.INTRODUCTION

Virtual Reality (VR), Augmented reality (AR), Mixed Reality (MR) are easy to implement with modern Head Worn Displays (HWD) for flight simulation and training, they can be and they already are available for basic and advanced flight learning. However, their use may be focused on type conversion, advanced training and periodical checks. In this case the modern generation pilot come from an experience that starts from very basic training, then more advanced training for procedural and line-commercial-flying and, in many cases they have already accumulated many hours in piloting airliners for commercial and passenger flights. This people are trained and checked in full flight simulators, which are extremely expensive. Therefore, their use is limited to the very minimum. However, type conversion and periodical checks are becoming increasingly focused on unusual flight conditions and emergencies. This type of training is particularly difficult since even experienced crews are not familiar to these situations. Therefore, you must revive and instruct the crews to these uncommon operations. The time is limited and you must focus on the essential and be sure to fix into the memory of pilots the essential. Furthermore, these operations should be the most instinctive possible, both for the diagnosis phase and for the correction one. Fixing into the memory requires the definition of stronghold experience inside human memory that activate known sequences. On the other side, especially during periodical checks, you cannot be too stringent; otherwise, you will ground most of your fleet in a short time. For this reason, VR/AR/MR are particularly useful in the most expensive phase of the training and, if properly used, they can significantly improve the quality of the training.

## II. THE "PEEPHOLE" APPROACH

The peephole approach is not new. For example, in the last part of the XVI century, Caravaggio and his school introduced a method to darken the "unrelevant" part of the painting, to focus the attention of the important subjects. This approach was appreciated by the buyers, mostly Church people, since the painting were used to teach concepts and facts to the churchgoers that usually were unable to read or even to understand fully the homilies (Fig. 1). In the painting of Figure 1, the Fortune Teller shows the essential. The dupe face on the left is highlighted (Fig. 2). This illumination is fundamental to introduce the person and to show that it is a "pure" being in full light. This contrasts hugely with the face of the "witch", the fortuneteller that is shaded. The witch is on the left part of the painting, being traditionally the left hand the "one of the devil". To make the evil person identifiable, her veil is nearly white (Fig. 3). Of course it cannot be white, since white is the color of the pure. The fortune-teller is a woman, because in the tradition females are closer to devil than males. The main object, the scrying palm of the dude, is in the center of the painting. It has very good lightning. This light, in the center of the scene, is the focus to the attention of the viewer. In addition, the hand of the fibber is illuminated, to connect the dude to the witch (Figure 4). The painting is a graphical way to represent a story. It is extremely succinct. Yet it is exactly into the way the human memory works. Focus points (anchors) and aggregation of patterns are detailed in a very natural way. The lights, the position and the known shapes give the mental path. This painting of Valentin de Boulogne introduces a way to imprint into student memory concepts in one the most effortless, compact and natural way possible.

FIG. 1. Valentin de Boulogne (c. 1591 – 1632), Fortune Teller

FIG. 3. The fiddler highlighted by a yellow circle

FIG. 2. The dude highlighted by a yellow circle

FIG. 4. The hands highlighted by a yellow circle

It is perfectly possible with modern HWD to darken, highlight, add arrows and circles, focusing parts of the scenery to imprint, into the students memory, fundamental events and operations. Sequencing can be done by illuminating or adding symbols to the part of the cockpit that is interested to the operation. In a full flight simulator, the headgear can be dressed during the learning or memory revamping phases and can be easily disposed during the repetition, operational and check phases. The "installation" of the HWD requires only the addition of a laptop computer with a jack for the HWD. It is also possible to have a wireless HWD to reduce at the minimum installation costs and discomfort. The glass cockpit has a "natural" positional based layout that is conceived to help the Pilot Flying (PF) and the Pilot Monitoring (PM) in dividing and handling their tasks. This positional knowledge can help the peephole approach. Figure 6 shows the glass-cockpit of an Airbus A320. The aircraft type is just for example, the emergency described afterwards and all the details are totally fictional. No direct reference to airplanes, facts, accidents, persons, procedures is contained in this document.

FIG. 5. The sights (arrows) point to the essential elements

In our purely fictional airplane, the ELAC (ELevator Aileron Computer) detects the over-speed, pulls nose up and puts both engines to idle. The elevator trim goes to the maximum nose up position. At this point, the updraft ends causing the airspeed to go below low speed stall with also the AOA (Angle Of Attack) in stall region. In this condition, the airplane aircraft enters slow speed stall aggravated by a nose up attitude with engines in idle. Now, aircraft rate of climb is at limit-range sink-rate. In our purely fictional airplane, pilots cannot override ELAC. However the PF instinctively puts the elevator control (joystick) full forward. At this point ELAC diagnoses the low sped stall, maximizing thrust and elevator control full forward. Elevator trim is still in the previous full nose up position. In addition, the ELAC is not programmed to take into account of the nose-down elevator input from the PF while in the nose-up-low-speed stall. The max thrust position of both engines causes the airplane to increase the AOA. Therefore, the aircraft cannot exit from the stall.

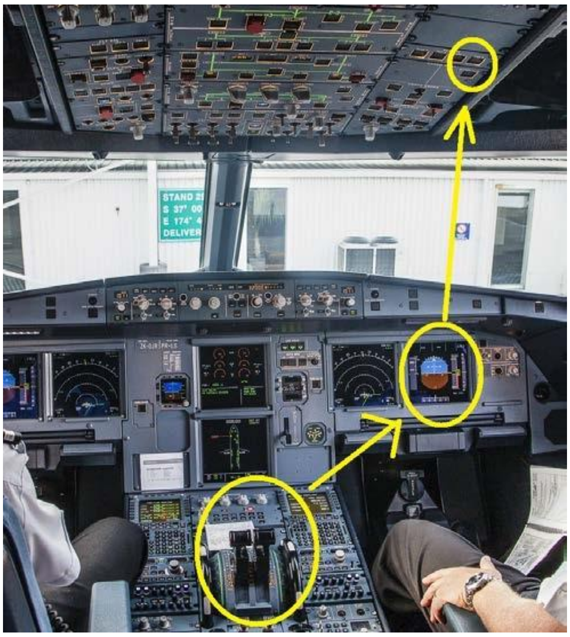

FIG. 6. A modern glass cockpit (the choice of the A320 cockpit is just for explanation, no direct reference to the true airplane should be taken)

Imagine that the right procedure to deal with this emergency is to pull the circuit breaker of the ELAC. If your trainee temporarily wears transparent HWD [1-4], it is possible to show the scenery of Figure 6. The three yellow circles point to the three critical areas. The trainee will probably start the sequence on the Primary Flight Display (PFD) on the right hand side near the centerline of figure 6. The airplane vertical speed, the nose position and the horizontal speed can be read from the PFD. Since the throttle is also highlighted by a yellow circle, he will go to the throttle, then he will follow the arrows again on the PFD. After the diagnosis, he will stretch a little bit to reach the circuit breaker on the upper right side ceiling of the cockpit. The three-step procedure is hierarchical also from the size of the circles, starting from the largest and moving to the smallest. The sequence can be afterward repeated without the HWD in a normal flying condition. However, the image of the three circles will stand bright into the pilot memory.

## III. GLASS COCKPIT AND VR

Flat-panels cockpits provide a sandbox in which ubiquitous flying scenarios can be showed and displayed in the most convenient way. Computer generated instruments and devices embedded in this environment give things and places the flexibility to vary the display or sense information. They provide virtual link between the physical world, in which they are located, and the virtual world that represents the flying machine. In this sense, the modern instrumentation of an aircraft augments it even without the use of classical augmented reality tools, such as HWD displays. In the vision of modern fly professionals, objects and information have the ability to make themselves known throw adaptive display representation, or correct input, to avoid dangers. Traditionally, Augmented Reality (AR) mostly looks at the external augmentation of objects or spaces. For the single pilot, the result is the same, no matter whether an object has display, or the information is projected onto it, or overlaid in a video-based or see-through HWD. The user adopts automatically the What You See Is What You Get (WYSIWYG) approach about information on the object. The most important factors that affect this perception are resolution and response time delay. For crew coordination, care should to be taken to trimming the images to provide a common perception of the HWD virtual overlay system. Environments in which multiple users can effortlessly experience the same augmentation instrumentation and projection is a prerequisite for the successful exploitation of ubiquitous computing and AR/MR (Mixed Reality). The generalized peephole is a metaphor for such harmonized and generalized view. Our objective in this paper is to review some important implications of the AR in modern aircraft training and high-line the relationships between AR and a larger class of technologies referred MR. For training, head-mounted see-through can revolutionize the use of modern monitor-based cockpit AR displays. “True See-through" or “Virtually See Trough” AR displays are characterized by the ability to see through the display medium directly to the external environment, thereby achieving both the maximal possible extent of presence and the ultimate degree of "real space imaging". The computer superimpose generated graphics optically onto directly viewed real-world scenes. Such displays are already a mature technology in some (mostly military) aviation systems, as either panel-mounted or head-mounted displays (HMD), but are currently finding new applications as a VR related technology.

## IV. GRAPHIC SYMBOLS AND AUGMENTED KNOWLEDGE

Graphic symbols form an essential part of most augmentative knowledge communication systems. Studies focusing on the way different graphic symbols are retained are common. Studies set out to determine how accurately 6-year-old children could identify and recognize 16 patterns, indicated that the use of 16 symbols lead to a significant improvement in test results. Symbols are an essential learning supports in achieving the goal of understanding and memorizing information. Use of symbols in learning may be relatively new, but human history counts many examples of people connecting vision and language for memorizing sequences of actions. Famous are the Spitfire drills: TPFF (Trim, Propeller, Fuel, Flaps) for takeoff and UPFF (Undercarriage Propeller, Fuel, Flaps) for landing [5]. Symbols and patterns are assistive when carefully selected. Pattern recognition has been studied for artificial intelligence, machine learning and knowledge discovery in databases. However, pattern recognition is both an approach to machine learning and to artificial intelligence. A definition of pattern recognition is: discovery of “regularities” in data to take actions. Pattern recognition finds its origins in engineering, and the term is popular in computer vision. Pattern recognition is aimed to formalize, explain and visualize the pattern, while machine learning traditionally focuses on maximizing the recognition capability. In machine learning, pattern recognition is the assignment of a symbol to a given input set. Discriminant analysis was introduced in statistics for this purpose. A classic example of pattern recognition is classification of sets to determine whether a given email is "spam" or "non-spam”. However, pattern recognition is a more general problem that can include symbols like in hand-written text recognition. Therefore, pattern recognition algorithms aim to provide a reasonable "most likely" matching of the inputs [6]. In this sense, computer-aided pattern-recognition helps to understand the human process and to identify the most effective symbols and sequence. Many common pattern recognition algorithms use statistical inference to find the best label for a given instance. They do not output a "best" label, but a list of the N-best labels with associated probabilities, for some value of N, instead of simply a single best label. The probability is a way to order your list. This is also the way in which human recognize symbols and patterns. For a probabilistic pattern recognition algorithm, the problem is to estimate the probability p of each possible label output of the set given a particular input pattern x,θ; i.e., to estimate a function f of the expression (1). $p(label \mid x,\theta) = f(x,\theta)$ (1)

Where the feature vector input is ***x*** and the function***f*** is parameterized by the list of parameters ***θ***. In a generative approach, the inverse probability ***p(x|label)*** is combined and estimated with the prior probability ***p(label|x)*** using Bayes' rule (2).

$$p(label \mid x,\theta) = \frac{}{\sum_{L \in all\, Labels} p(x \mid label_L)\, p(L \mid \theta)} \quad (2)$$

Where the labels are discretely distributed. The best value of ***θ*** is typically optimized on the training data (smallest error-rate). Essentially, this combines maximum likelihood estimation with the regularization procedure that can be viewed as placing a prior probability $p(\theta)$ on different values of $\theta$ as in equation (3).

$$\theta^* = \arg\max_\theta p(\theta | D) \qquad (3)$$

Where $\theta^*$ is the value used for $\theta$ in the evaluation. $p(\theta|D)$ is the posterior probability of $\theta$ (4).

$$p(\theta | D) = \left( \prod_{i=1}^{n} p(y_i | x_i, \theta) \right) p(\theta) \qquad (4)$$

As it can be seen from equations 1 to 4 the problem of automatic pattern recognition is complicated by the variables $\theta$ to each input $x$. Assuming that the trainee cognitive and learning process is similar to the one of the computer, it is necessary to limit the number of variables $\theta$ to the minimum. A rectangular pattern contains 4 lines and 4 lengths, for a total of 8 variables. The circular pattern of Figure 6 is therefore to be preferred having two variables (circle/oval, size). This simplify the recognition, the memorization and the retrieval process of the trainee's mind. The arrow has also two variables (line, length), being the arrow point seen as an accessory of the line, like the color. The color and the arrow are therefore less important in the hierarchy of the cognitive process. Therefore, they will be forgotten earlier. This fact does not affect the essential of the three area emergency pattern of figure 6. In addition, the arrows are superfluous. In fact, the size of the ovals give the same information. Since the recognition approach is also hierarchical in time, it is important to put the most probable or dangerous procedure at the end of the training process.  This approach is contrasted by fatigue and stress that reduce the cognitive capability of the trainee.  However, the instructor can evaluate tiredness easily, if the HWD is integrated by electroencephalography (EEG) [7]. Modern EEG does not need anymore the conductive gel and can be worn as a cap between the HWD and the head. The relationships between memory processes and oscillatory electroencephalography (EEG) are well established. Neurofeedback in training (NFT) gives the instructor the possibility to amputate the stress and confidence levels of the trainee. In addition, the attention can be easily evaluated.

## CONCLUSION

After exploring the technological issues involved in nowadays-digital culture and how pilots' training and aviation science lessons could be designed incorporating relevant and interactive software into a sound pedagogical strategy for aviation students and professionals, our study focuses on how to address in-class engagement, academic & learning performance, and advance training of Millennial, Generation Z, and low experienced pilots to improve academic success rates. Depending on the definition, Millennials (also known as Generation Y) are persons reaching young adulthood in the early 21st century. Therefore, the 1981 to 1996 birth cohort is a "widely accepted" definition. Generation Z is the demographic cohort after the Millennials typically use the mid-1990s to mid-2000s as starting birth years. Low experienced pilots mean in this context pilots with less than approx. 200 flying hours. In the further course, these are referred to as Target Group. Those students' attitude, interest, and confidence towards their learning is of concern to the aviation industry and airlines. Research indicates that aviation training programs can increase graduation rates and improve in-flight performance by improving student metacognition skills and enhancing their understanding of learning strategies.

The "peep hole" approach allows focusing the attention of the pilot on critical issue even on full flight simulation on type conversion or periodical checks. This approach is particularly efficient in critical situation simulation and correction. The possibility to wear Head Worn Displays makes it possible to add virtual symbols to highlight positions and sequences. A careful choice of these symbols and highlights speeds up the learning process in a very significant way. This paper describes how to make it starting from Artificial Intelligence learning methods. This approach is particularly important when training takes place in full flight simulators where cost is high and time limited.

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