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ANALYSIS OF THE P-51D ACCIDENT IN ENGLAND IN 2017 USING COGNITIVE ERGONOMICS CONCEPTS

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SUMMARY: In 2017, after intermittent engine failures during his performance at the air show in Duxford, England, the pilot of the P-51 Mustang had to make a forced landing on a farm close to the landing strip, causing damage only to the aircraft and without casualties. Air accidents are usually analyzed from the point of view of cognitive ergonomics, seeking to elucidate the aspects that normally cause or contribute to human error. However, it can be highlighted that the pilot's actions in this accident, for the most part, function as good examples within the concepts of cognitive ergonomics. Based on these concepts, based on the literature review regarding performance and human error, attention, observation of operations in cockpits and control rooms of nuclear power plants, the authors analyzed reports, lessons learned and two videos of the accident, available on the internet.

KEYWORDS: Aircraft Accident; Human Error; Pilot

INTRODUCTION

Aviation is a domain in which several ergonomic concepts apply. Initially, anthropometric concepts, relating topics such as the shapes and sizes of control elements and displays and the crew member's functional reach with these items were the subject of studies and have been included for some time in design guides and standards, such as MIL-STD -1472 (US Department of Defense, 2012). Even in a cockpit that meets all of these ergonomic principles, there is still room for what is known as “pilot error” to occur (Fitts and Jones, 1947).

Since then, several factors have contributed to improvements in aviation safety, but accidents still exist. Especially in commercial and military aviation, it is from the point of view of cognitive ergonomics and complex and automated systems that accidents are analyzed and studied, mainly through the basis provided by studies by Bainbridge (1983), Rasmussen (1983), Wickens (1988, 2010), Reason (1990) and continually improved, as in the case of the “Human Factors Analysis and Classification System”, HFACS, Shappel, 2000 and Lower et al, 2018).

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The authors of this study analyzed two videos (Air Safety Institute, 2018; High Flight, 2017), the report (AAIB, 2017) and two news reports (Airscape 2019; Hirschman, 2018) about the accident, evaluating the actions observed in the videos and described by the pilot based on the ergonomic concepts shown in the literature review.

ACCIDENT DESCRIPTION

On July 9, 2017, during the final part of the second day of performances at the Duxford, England air show, the P-51D Mustang aircraft was part of a formation pass with other historic aircraft over the runway. Before executing the maneuver, the pilot changed the fuel tank, a standard procedure carried out every 30 minutes of flight, selecting the tank on the right wing. After passing, the formation of aircraft rose to a height of approximately 300 meters and, to maintain position, the pilot had to continually adjust the power lever. During one of these activations, the aircraft experienced the first anomaly in the engine's operation, which quickly resumed operation, but began to show intermittent behavior. The pilot made an attempt to approach the runway, but the aircraft's glide was insufficient for landing, given the unreliability of the propulsion and the low height. As an alternative, the pilot looked for a favorable point for an emergency landing in the nearby wheat fields. During the descent procedure, low and close to the runway, the engine stopped permanently, causing the landing to occur on a farm (AAIB, 2017, Airscape, 2019 and Hirschman, 2018), with no victims and only damage to the aircraft itself. .

This is one of 30 accidents that occurred at aerial exhibitions that year around the world, of which 34% occurred due to mechanical failure, double the historical average for this type of failure (Barker, 2018).

THE AIRCRAFT

The P-51D Mustang, registration G-TFSI (Fig. 1) was a single-seat fighter aircraft originally delivered to the US Air Force in 1945, remaining in operation until 1956. In 2007, after six years of work to review, update and conversion of the original P-51D model to a two-seat trainer model (TF-51D), the aircraft was transferred to Duxford airfield, England (AAIB, 2017). The plane was sent to the USA for repair and, the following year, it was shown at the same show (AIRSCAPE, 2019).

Figure 1 - TF-51D Mustang “Miss Velma”, registration G-TFSI, one day before the accident

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The P-51 Mustang is an American World War II fighter, originally designed by North American Aircraft for the Royal Air Force of England in 1940. In just 117 days it was designed and the prototype made its first flight. After the US involvement in that war, it began to be used by the US Army Air Force, being used very successfully in both the European and Asian theaters. More than 14,000 units were produced, with the P-51D model being the most produced, with 8,302 units (Smithsonian, 201?). Because of the end of the war and the introduction of jet fighters shortly after it ended, these fighters were sold as surplus to various air forces, companies and even individuals. Currently, several P-51s are still maintained in flying condition by individuals, museums, foundations or companies, whether for racing or aerial exhibitions, which is the case in which this particular model fits. Figs 2 and 3 highlight elements that will be mentioned later: the power lever, the hood opening lever and the machine gun openings in the wings.

Figure 2 - Cockpit of a P-51D. The arrows show the power lever (left) and hood opening crank (right)
Source: Adapted from Smithsonian (201?), with distribution permission CC0 (CC, 202?a)

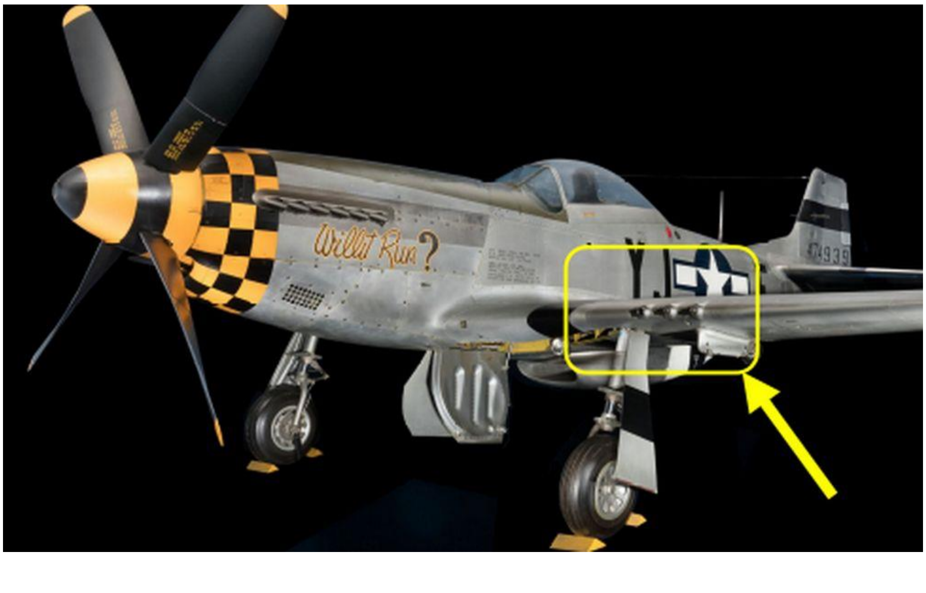

Figure 3 - Machine gun opening on the wings of the P-51D
Source: Adapted from Smithsonian (201?), with distribution permission CC0 (CC, 202?a)

THE PILOT

The pilot was Mark Levy, flying for aircraft restoration company Anglia Aircraft, which owned the aircraft (Airscape, 2019). He is a pilot for British Airways and has extensive experience in aerial displays on other aircraft, having participated in them since 1989. He has a total of 21,000 flight hours on various aircraft, but only 9 on the Mustang until the day of the accident (AAIB, 2017 and Hirschman, 2018).

LITERATURE REVIEW

Rasmussen begins his study by emphasizing that human beings do not act, or behave, simply as input and output devices of the deterministic type and that our behavior is modified depending on the signals emanating from the objectives to be achieved, which was defined as teleological behavior (Rosenbluth and Wiener 1943, apud Ramsmussen, 1983). In this context, he sought to distinguish the categories of human behavior in a qualitative way and did so into three levels of human performance, which are skill, rule and knowledge. The different use of information available at these performance levels has distinctions, which led him to define them as signals, signs and symbols, all within the model known as SRK, from the English Skill, Rule and Knowledge (skill, rule and knowledge) .

Based on this study and the areas of error research that divided error into "slips and lapses" and "deception", Reason proposed the Generic Error-Modeling System (GEMS), in which he creates a structure of understanding the flaws in each of those levels of human performance. An interesting concept is the "Strong-but-wrong" mindset for problem solving, in which procedures accumulated over years of practice can be triggered and applied at inappropriate times, due to, for example, out of context or due to lack of information to properly diagnose the problem.

In this same work, a distinction is also made between active errors, those whose consequences are observed immediately, and latent errors, which are errors caused not necessarily by operators, but by other people involved in the process, who may even be the designers. , which cause failures that remain hidden and reveal themselves at certain times. The alignment of active and latent failures, which is a possible sequence that culminates in an accident, became known as the "Swiss cheese theory", as the different layers of "defense" of a system can contain, for different reasons, failures and imperfections. which end up not preventing the accident they were supposed to prevent.

Based on this distinction between active and latent failure and the Swiss cheese theory, the human factors analysis and classification system (HFACS) used in aviation was developed, which is described by Shapppel (2000) and Lower et al. (2018). The main reason for developing this system is the fact that the Swiss cheese theory provides few details on how to apply it in the real world in a practical way (Kelly, 2019). This system describes four levels of failure: unsafe acts, preconditions for unsafe acts, unsafe supervision, and organizational influences. It should also be considered that there are situations in which the "problem is not completely understood and formal procedures and response options are not available" (Shapppel, 2000).

Human performance levels are, in a way, triggered by information originating from the context in which the equipment and operator are inserted. But the full availability of information is not a guarantee that the operator will be at the most appropriate skill level, as human beings have strong limitations in their processing capacity, causing information overload. Wickes et al. (2010) classifies our attention depending on the treatment given to this information, that is, to external stimuli (or part of them), as selective, focused and divided attention. However, the sampling of signals within these attentional modalities is affected by memory limitations and stress conditions (Wickens, 1988). Regarding attention and performance in tasks, Latorella (1999) states that interruptions through the auditory canal increase execution time and the making of errors in these tasks. It is interesting to note in that study by Wickens that attention to a stimulus can happen unconsciously and, in a way, activating long-term memory, at a level called pre-attentional. This level is observed by Woods (1995), when he reports that nuclear power plant operators realize that something is happening, also through the sounds produced in the form of "clicks" by the electromechanical devices that control the control bars, which adjust the power of a nuclear reactor. Without necessarily looking at the parameters of the nuclear plant, operators quickly realize that the automatic system is, for some reason, acting on the movement of these bars. This is called by Mumaw (2000), in his field study with nuclear power plant operators, as "taking advantage of unmediated indications", that is, information obtained even when there are no instruments to do so, such as a bomb. resounding and the noise of intensely operated electromechanical indicators. Gaver et al. (1991), in the research where they synthesize intrinsic sounds of the system in a simulated environment and improve the efficiency of the operation, by creating suitable "acoustic icons", mentions that the sounds made by car engines are not projected, but they are properly used by the people to know if they are working correctly or not.

In addition to the issue of information overload, affecting attention and processing capacity, signals can be ambiguous, carrying meanings that do not help in diagnosing a problem and the consequent decision-making to resolve it (Orasanu, 1998). In high-risk and time-pressured situations, such as during abnormal operations and emergencies, decisions are often made based on comparing what they can identify as a pattern they have already learned, known as a decision model. based on recognition (RPD, Recognition-primed decision model, KLEIN, 2008).

Bainbridge argues that even in highly automated systems, there are still occasions for error and, ironically, such occasions may still increase, due to the loss of operators' motor skills as they stop being an active part of controlling a process and start only monitoring and intervene in the system when automation fails. We highlight the cognitive abilities of long-term knowledge and working storage in this study.

Regarding the cognitive observation of an operation in the cockpit, we can mention the study by Hutchins (1995), which is based on the analysis of manuals for the McDonnell Douglas MD-80 aircraft and on direct observation of the landing, inside the cockpit. In this study, different steps, procedures and devices used are analyzed from the point of view of cognitive ergonomics. This observation shows that this plane, the MD-80, on the landing trajectory, needs to change the flaps configuration depending on the weight and speed of the aircraft. Although these values are contained in the manual, which is available to pilots at all times, a method is needed to reduce the crew's workload and short- and long-term memory, in this phase of the flight with great time pressure. This is done by placing indicators around the speedometer. When each speed is reached, the crew member monitoring the speedometer reports the value to the other, who adjusts the flaps.

ANALYSIS OF THE PILOT'S ACTIONS FROM THE POINT OF VIEW OF COGNITIVE ERGONOMICS

Right at the beginning of the first video (Air Safety Institute, 2018) the pilot acts a lot on the power lever (Fig. 2) and it is possible to observe, through the camera mounted on the helmet, that he is observing another plane and trying to maintain the flight in graduation. with him (also seen in High Flight, 2017), in focused attention. Then, at 47 seconds, the engine presents its first failure and we can clearly see the pilot's skill level, as he works on the power lever, trying to return to the power required to maintain the flight in formation. But the engine soon starts working again, however, it operates intermittently. After 30 seconds, the pilot realizes that the engine's performance is no longer reliable and “behavior patterns” emerge, causing him to keep the aircraft at an appropriate speed to maintain lift in flight, move the canopy opening lever (Fig. 2) and start looking for emergency landing options in the surrounding fields. This denotes the level of performance as a rule, which triggers the RPD. Opening the canopy is important in this case, as damage to its opening mechanism in a forced landing could leave the pilot trapped in the cabin. This goes against the manual, which recommends jettisoning it, but he judged it not to be a good solution, trying to prevent a piece weighing almost 150 kg from falling onto an adjacent highway, with a lot of traffic. In the HFCAS classification, this falls under an exceptional violation, within an unsafe act (Kelly, 2019). However, the engine starts working again (1:32 of the video). Thus, he states that it is not a total engine failure, but rather a “partial and intermittent engine failure, which is much worse than a total failure”, in addition to the engine not exhibiting any other symptoms of the possible cause of this intermittency. When stating that this is much worse than the first type of breakdown, it is clear that, now, the level of skill has become that of knowledge. Up to this point, the signs and signals come exclusively from engine noises, as the pilot does not mention the use of instruments to obtain more information nor can he observe a more attentive observation of any instrument. The head movements indicate greater concern in the formation flight he was in and looking for a landing spot. Later in the interview, he states that it could be an episodic problem, like water in the fuel. This is the level of skill, certainly coming from experience with lower power planes, but the Mustang consumes “40 gallons (150 liters) of fuel per hour”, so a small water intake could not cause such a problem. This is the mental schema called by Reason “strong-but-wrong”. Communication with air traffic control was impaired, as the pilot was overloaded with information, operating at a level of knowledge and focused attention. He reports that he is able to hear, but not hear, process, and respond to this communication. In this case, traffic control notes that he is coming in for landing, but the landing gear is not down. At the skill level, the pilot keeps the landing gear retracted to avoid the risk of rolling over during landing, something common in this type of aircraft.

Although he is an airline pilot, flying large commercial planes with a high level of automation and complexity, he maintains the habit of performing spins and landings with the engine turned off on a monthly basis, in order not to lose his motor skills (Bainbridge, 1983). Moments before landing, he lowers the flaps completely, so that the plane loses a little more speed before touching the ground, once again, operating at normal level.

In addition to the engine noise, the pilot uses “unmediated indications” (Gaver, 1991 and Mumaw, 2000) when he notices that the horizon “rises” through the windshield at the same time as there is a whistle made by the air passing through the exit of the pipes. of the machine guns on the leading edge of the wings (Fig. 3). This occurs, in the P-51, when the plane has a high angle of attack, normally occurring during landings, indicating that the laminar flow of the wings approaches stall (Hirschman, 2018). Combining these two pieces of information, high angle of attack and loss of altitude, he realized that the time to land was close.

CONCLUSION

Analyzing this accident from the point of view of cognitive ergonomics allows us to exemplify and contextualize several widely used concepts. In this way and combined with the HFACS analysis system, it is clear that, in this case, there was no alignment of the failures predicted in the “Swiss cheese” theory and that the pilot's actions, which led to a landing only with consequences for the aircraft itself , for the most part, can be considered good examples of the concepts used.

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