Pilot errors in perspective of the situated action: the case of AF447 accident

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On 1 June 2009 the Airbus 330 of Air France coming out of Rio de Janeiro to Paris crashes into the Atlantic Ocean, killing all 228 people aboard. One of the causes of the accident indicated by official agencies were errors made by pilots, which combined with technical failures led to the loss of control of the airplane. Human error was again appointed as the last link in the chain of events leading to the accident and, therefore, as their immediate cause. In this paper we propose an alternative explanation, which is not limited to the identification of errors by the crew, but proposes an explanation of errors themselves. In a cognitive analysis of accidents based on the concept of situated cognition and action, the error is not the point of arrival of the diagnosis of the causes of an accident, but the starting point. Thus, we return to the official results of the accident, specially the analysis concerning the expected behavior of pilots regarding the encountered unforeseen and the breach of aviation rules, during the four minutes before the fall of the aircraft in the ocean. This critical analysis makes room for a more comprehensive explanation of the behavior of pilots, based on another framework – the cognitive analysis of accidents – not yet incorporated into the official models of human factors analysis in safety and leads to different actions' prevention.

Keywords: Human Error, Accident Analysis, Situated Action, Human Factors.

1. Introduction

On 1 June 2009, the AF447 flight, Rio de Janeiro / Paris, with 216 passengers and 12 crew members, crashed into the Atlantic Ocean leaving no survivors. A technical investigation was opened by BEA (Bureau d'Enquêtes et d'Analyses) - French authority responsible for analyzing the civil aviation accidents - to clarify the causes and propose preventive measures. This survey generated 4 official reports, published between July / 2009 and July / 2012. During this period, more or less conclusive analyses were produced, which were crystallized in a diagnosis (table 1).

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
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<tr>
<td>01/06/2009</td>
<td>Flight 447 crash.</td>
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<tr>
<td>06/06/2009</td>
<td>Discovery of the first wreckage of the plane.</td>
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<td></td>
<td>Publication of the first progress report by BEA.</td>
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<td>02/07/2009</td>
<td>Document the first elements of the accident through description of the first facts and wreckages.</td>
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<td>The plane was not destroyed in flight and &quot;seems to have reached the surface of the water with a strong vertical acceleration&quot; (BEA, 2009a, p.40).</td>
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<tr>
<td>17/12/2009</td>
<td>Understanding the accident through the recovery of the wreckage, the weather conditions, the messages with the air traffic control and records the speed probes.</td>
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<td>The plane was entire when it hit the water, the nozzle tilted up, and with an important vertical speed (BEA, 2009b). Recommendations relating to flight records and equipment certification were made.</td>
</tr>
<tr>
<td>01/e</td>
<td>Recovery of two black boxes, one containing the records of the flight data and the other</td>
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The BEA results shown in the table above emphasize human error as the main cause of the accident. In this paper we propose an alternative explanation, which is not limited to identify mistakes made by the crew, but proposes an explanation of the own mistakes. In cognitive analysis of accidents based on the concepts of action and situated cognition, human error does not explain the accident, even when it presents itself as the immediate cause, or the last link in a chain of events (Hutchins, 2000). Why this error has happened is that it requires explanation. In the case of Flight 447, starting from the same data of the official reports but reconsidered with the help of another analytical framework, it is possible to explain the accident in depth, explaining the failures of cognitive representations that pilots, under the circumstances, have devised. These are representative failures that led to the decisions and misguided actions of the pilots. This critical analysis makes room for a more comprehensive explanation of the behavior of pilots, based on another frame of reference - cognitive analysis of accidents and situated action - not yet incorporated into the official models of analysis of human factors in safety.

2. A new approach to accident analysis: the situated action and distributed cognition

In the years before the creation of the Swiss cheese model (Reason, 1990) and the psycho-organizational model (Llory, 1999) of accident analysis, it was revealed also some works that developed concepts of cognitive anthropology of modern situations (Lave, 1988; Scribner, 1986; Hutchins, 1995), showing the inadequacy of human models as a symbolic system for processing information.

Suchman (1987) introduced the concept of "situated cognition", giving priority to action in relation to the dominant cognitive concepts by showing how an operator interacts with interactive and sophisticated photocopiers. The author proposes, as opposed to action guided by a plan, the notion of "situated action", evoking the need to consider the "live trial" at any moment, the meaning of the particular circumstances and to explore the dynamic relationship between knowledge, action and circumstances. In this line, Theureau (2004) states that cognition is not located in the head of the actor, but between him and the situation in which part of the other actors and instruments.

Cognition and intelligence are not purely individual capacities: there is a collective intelligence, distributed among the group members. Hutchins & Klauser (1996) call this concept "distributed cognition" and propose analytical models that allow to describe and explain the cognitive properties of the system as a whole and not the ability of a single individual. The focus of distributed cognition, and the situated cognition, precludes a cognitivism centered on the individual, where the brain would be the central point of data processing system, culminating in mental representations that would direct action (Hutchins, 2000). Theureau (2004) deepens these reflections within the course of action theory, emphasizing the concepts of "incorporated action" and "pre-reflective consciousness" as additional hypotheses to characterize the
experience. According to the author, "human activity is accompanied at all times from a pre-reflective consciousness (or experience) which includes what we know as consciousness, but also all the implicit activity defined at every moment" (Theureau, 2004, p.21). Thus, the possibility of an adequate description of the practical activity depends not only on the researcher who observes and interprets the behavior of the actors. It depends, first, on the implementation of explicit methods of pre-reflective consciousness of the actors, which is present at every moment of their practical activities.

These theories help us to better understand human reactions in emergency situations. Action, perception and cognition are intertwined and mutually supportive. The speed of signal detection of an anomaly is associated with our ability to modify the representation of the current situation and are often out than was expected as a previous representation. Therefore, unexpected or surprising reactions may occur according to the context (JOUANNEAUX, 1999). Commonly, these actions, when they prove inadequate, are classified as "human error", and are present in about 80% of air accident analyzes (Foushee, 1984).

These theories of activity, considering other dimensions as the organization of work, situated action, distributed cognition, incorporated action and pre-reflective consciousness, allow us to escape the reductionist view inherent in the behavioral approach in accident analysis. The unit of analysis should be not only the behavior (behaviorism) or the mental representation (cognitivism), but the interaction between these elements of action with the environment (Theureau, 2004). Behavior or human factors, therefore, should not be seen as the cause of unwanted events, but as the result of an interactive construction process, which comprises the man (through their actions and their cognitive development), the organization of work and the technical environment in which it is inserted.

3. Methods

To develop this approach, a comprehensive study on the 4 official reports published by the BEA (between July 2009 and July 2012) was conducted. This study was focused on theory of situated action, as well as the analysis of information given by pilots and former pilots experienced with Airbus and Boeing aircrafts in official interviews. To try to compensate for the absence of the main actors - the pilots - we have confronted the possible explanations provided by the theory of situated action with explanations from of pilots and former pilots, given in official interviews about the accident, in particular as to the meaning that may have been assigned by staff in the heat of action, and the signals provided by the aircraft during the crash. Supported by this evidence, we will discuss the limitations of the BEA’s main conclusions and propose an alternative line of explanation that shows the gaps in the official explanations associated with the behavior of the pilots.

4. The investigation of the accident according to the BEA

4.1 Reconstitution of the crash

Flight 447 Air France took off from Rio de Janeiro, at 21h29 the day May 31, bound for Paris, carrying 228 people. The cockpit staff was composed of two co-pilots, one with 6000 hours of flight, called in this article Copilot 1 (Co1), the other with 3,000 hours of flying, called Copilot 2 (Co2) and the Commander, with 11,000 hours of flight. As soon leaves the Brazilian coast, the Airbus A330 enters a turbulent area, common in the Atlantic region. The aircraft is with the autopilot in charge. Shortly before 2 am, the Commander will rest, leaving two co-pilots in the cockpit. About ten minutes after departure, there is a technical incident: the freezing of 3 external speed sensors (or probes Pitot) of the aircraft. As a result, the speedometer falls brutally, turning off the autopilot, and the command automatically revert to manual mode. The flight operation is now a responsibility of the co-pilot. About ten minutes after departure, there is a technical incident: the freezing of 3 external speed sensors (or probes Pitot) of the aircraft. As a result, the speedometer falls brutally, turning off the autopilot, and the command automatically revert to manual mode. The flight operation is now a responsibility of the co-pilot. At this time, Co2 pulls the lever (or joystick), raising the "nose" of the aircraft.

Moments after this action of Co2, the plane goes into sustaining loss (or stall), which can occur with the airplane in different configurations. In the case of Flight 447, the plane reaches the "coffin corner", goes out of its flight cone and lose horizontal thrust force (figure 1). In other words, the aircraft begins to fall. About 4 minutes after the start of stalling, the aircraft crashes into the sea, a vertical velocity of 200 km / h. There was no distress message sent by the crew.
4.2 Limitations of BEA's investigation

The final diagnosis of BEA (2012) suggests that the pilots did not respect some basic safety rules in civil aviation. In the A330, the trip computer proposes actions to be performed in most cases of breakdown or emergency during flight. From information provided by the monitor, "the team must analyse and confirm the nature of the fault before starting any anomaly correction action" (BEA, 2012, p. 110), or, in cases where the monitor does not identify the anomaly, "the expected reaction of the team implies immediate memory actions to stabilize the situation" (BEA, 2012, p. 108).

The plane begins to leave its flight cone and the stall alarm goes off. The BEA report (2011, p.79) evokes that despite this, "none of the pilots referred to the loss of support of alarm". This is associated, by BEA, to the absence of further training on this. "The recognition of the stall warning, even associated with the buffeting, supposes that the staff attributes a minimum legitimacy to the alarm. This implies, on the other hand, a sufficient previous experience, a minimal cognitive availability and understanding of the context, knowledge about the airplane (and their modes of protection) and on the physics of flight "(BEA 2012, p. 206).

In addition to the failure to identify the stall warning, the action to pull the stick or instead of pushing it was also justified by the BEA: "the excessive nature of pilot's actions (CO2) can be explained by the surprise and emotional charge at the disconnection of the autopilot, amplified by the lack of practical training of staff in high-altitude flights "(BEA, 2012, p. 179). The justification of the BEA is therefore based on human sensory thresholds, in the emotional charge of the situation and the lack of proper training for the identification and management of anomalies (failure to identify the alarm, failure to identify the stall itself and the fact that the Co2 pull the lever rather than push it). According to the BEA these are reasons why the pilots to make mistakes considered basic.

Explanations like these are crystalline, but only because they represent the view of an external observer, which occupies a privileged position in relation to the pilots in the cockpit. The post-accident analyst knows for sure what position was the plane at the time, and thus which rule should have been applied to keep it under control. In these testimonials, the interaction between the set of parameters of the context were not considered.

The conclusions of the BEA on the accident added very little to the explanations published in previous reports, why not consider the situated action and the interaction between the set of parameters that make up the context. It must be noted in addition to these physiological mechanisms or lack of training, as in the course of action, operates selective perception.
5. **The accident from the perspective of situated action / cognition**

Why the pilots did not understand the real condition of the plane? Why did not recognize the signals emitted by the aircraft for the stall, such as alarm and the buffeting? Why Co2 pulls the stick worsening stall condition? Why the commander did not have a more energetic reaction and did not pick the commands when it returns to the cockpit?

None of the signals emitted by the aircraft identified the direct cause of the abnormality occurred, that is, the freezing of Pitot tubes. Only the immediate consequence of this anomaly (sudden reduction of speed) is displayed on-board computer, but not its cause. Once the probes are frozen, pilots see an abnormal speed on the panel and act according to this sign, believing it to be true. However, this signal is not real, because the speed of the plane had not been changed, only their indication. The initial anomaly is on the speed sensor and not on the speed itself. So, all actions are performed on the basis of this interpreted situation and not on the actual situation.

In this sense, Gérard Arnoux, Air France pilot, evokes that if the Pitot probes had not given false indications of speed, the accident would not have occurred. According him, the Co2 pulls the stick brings the plane to loss of support because "he has a very low speed under the eyes" (France 3, 2012).

The pilots do not know the actual speed in which they are. During a trip so far without incident, the first available abnormality signal is the speed indicator. However, they are unaware of the anomaly in the Pitot probes. The instantaneous speed displayed by the panel does not necessarily mean that there was an abnormality in the speed probes, because this anomaly could be in any other system component. The failure of the Pitot probes is obvious only after the accident. In this sense, a hypothesis formulated by Co2 may have been a real change in the speed of the aircraft, and not just the change in the electronic indicator. Already he had no information of the actual speed and did not know the technical incident, pull the stick may have been an attempt by Co2 to gain speed, which had the signs below the actual speed.

The CO2 then pulls the stick and places the aircraft in a condition that leads to loss of support. The aircraft begins to fall, and some signals are issued by it: the buffeting starts and the trip computer shows a unstable velocity, an altitude in progressive decrease, and an artificial horizon outside the stable position. For pilots, these signs are incomprehensible and this situation lasts until the shock with water.

The buffeting, according to Gérard Arnoux, is perceived in a clear and peaceful sky, but when we are in a turbulence, notice the physical difference between the stall and such turbulence is extremely difficult, or impossible, especially within a geographical area admittedly of great turbulences and under strong storm (France 3, 2012). Thus, by themselves, the sensation of turbulence was not an abnormality indicator and could be regarded as resulting from external conditions.

From the time when the airplane comes into stall, the altitude indicator shows a gradual loss and the riders make constantly reference to it. "Let's get to the hundred level," says Co2, referring to the proximity to the sea level. At the same time, the artificial horizon indicates that the wings are not in horizontal position, which demonstrates instability of the aircraft. "Put the wings horizontally", verbalizes the Commander in order to stabilize the aircraft. At this point (and by the end of the flight), the pilots have no doubts that the plane is falling. The misunderstanding lies in the reason of the fall and not in the fall itself: a same state can be caused by different circumstances of the world or of the complex subsystems of an airplane.

Three points seem, therefore, be a priority for pilots: gain altitude, gain speed and stabilize the aircraft's wings. With multiple alarms sounding at the same time, an indicator showing the altitude falling continuously, and another showing the instability of the aircraft, the biggest concern of the pilots was not analyze all the alarms, identifying which were reals to eliminate the ambiguities of the information system, but, before that, to understand why the plane was out of control and why the altitude decreased gradually. So it was not important to understand the alarms, as these signs were not decisive in the resumption of control of altitude.

The priority was then regain altitude and control the wings of the aircraft. It is probably for this reason that the CO2 continues to pull the stick, trying to gain altitude. This action is generally effective, but not in stall situations. At this moment, we must do the opposite, that is, push the joystick to regain support and, from that, gain speed and altitude to recover. Pierre Henri Gourjeant, Executive General Manager of Air France at the time of the accident and former fighter pilot, said the biggest misunderstanding is exactly at this point. He said the pilots did not understand why they were in raised position (with the stick pulled and the artificial horizon showing the position to cabrar) and yet, they descended (France 3, 2012).
So lack of knowledge about the situation was widespread. It is unknown the origin of anomalies (freezing of Pitot probes) and the loss of the aircraft support. Inside the cockpit, the information received is of inconsistent speed, altitude in progressive decrease and the aircraft's wings in unstable position. Given this situation, continue pulling the joystick levers seems the most reasonable solution to be taken to recover the aircraft's altitude.

6. Conclusion: Possible preventive actions

To advance in the system security management, it is necessary to know the representations of workers and the manner in which they deal with the variability of the medium. It is undeniable the technical contribution in the evolution of security levels, but the technical choices are ambivalent: they help to reduce the frequency of accidents, but at the same time, they generate other accidents, creating obstacles to the activities of the operators. The question that comes up is how we can move forward in a concrete way on security issues when the automation complexifies the technology, becoming more obscure the causes of technical flaws?

A management system based only on prescribed security can become dangerous for not offering all conditions to forecast risk situations (Daniellou et al, 2011). The expertise of workers is a fundamental component of systemic safety, and to develop it, it is necessary to know the representations of workers not only about the risk situations, but also on everyday work situations. Make visible these representations, as well as the adaptations and adjustments to the workers are therefore crucial to build an effective security management (Amalberti, 2013). So, do not just develop reaction capabilities from training in simulators; we must also recognize and socialize collective memory that teams accumulate in real situations flight. The methods of "return of experience" should be revitalized from what is already known about how memory works in situation (Hutchins, 2000). Make visible the knowledge and skills of workers know how to organize a much more effective return of experience (Gaillard, 2005).

Today, when the technical reliability continually improves, but accidents happen as a result of minor flaws that spread unpredictably in a complex system, prevention becomes even more dependent on subjective perceptions not formalized. The "goose bumps" (Dreyfus, 2012) is announcing the possibilities to improve safety: extreme situations are perceived by the body in action, by the practical intelligence, before they can be understood consciously or verbalized. This requires approaches based on situated action theory.

So one of the keys to advance on the safety of airplane systems, is the organization of a return of experience able to develop training and simulations in emergencies. This is be possible only if the return of experience is based on real situations, that is, from lived and controlled situations, but in which the pilot or crew had some difficulty. This practice could help to reproject the automations and define the necessary and relevant information to feed the simulations. This would be a way to develop the safety at work and do the organization make progress due to the inherent learning to real activity and its continuing development.

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