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Original Article

Heading towards adaptive behavior in aviation training

No rumo de um comportamento adaptativo na instrução aérea

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Luiz Mauricio de Andrade da Silva[1,2]
Rubens Nunes[3]

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Abstract: Every year, approximately 140 military aviators graduate from the Brazilian Air Force Academy, an operational environment that is quite safe. However, the operational definitions of the variables in the piloting instruction are based solely on functional classifications; thus, they are still lacking the constructs and definitions that would provide better levels of communication among flight instructors and cadets. The research problem is framed in system one (intuitive) of decision-making, using heuristics. The literature concerning the heuristics applied to human judgment and decisions have been revisited. Following this, the focus was on the functional classifications that have already occurred in aviation, and situations in which aviators would benefit from heuristics as a starting point to the process of building constructs, and one proposal for an adaptive form of instruction.
Keywords: Military piloting; Constructs; Relative weights of variables.

Resumo: *A Academia da Força Aérea forma, por ano, aproximadamente 140 aviadores militares em um ambiente operacional bastante seguro. No entanto, observa-se que as definições operacionais das variáveis da instrução se baseiam apenas em classificações funcionais, carecendo de construtos para melhor comunicação entre instrutores de voo e cadetes. Enquadra-se o problema de pesquisa no sistema 1 (intuitivo) de decisões, com o uso de heurísticas. É um estudo teórico. Recorremos à revisão da literatura das principais heurísticas de julgamento humano em decisões. Posteriormente discutimos as classificações funcionais já sedimentadas na aviação e as situações em que os aviadores podem se beneficiar das heurísticas, iniciando o processo de elaboração dos construtos, e uma proposta de instrução adaptativa.*
Palavras-chave: *Pilotagem militar; Construtos; Pesos relativos das variáveis.*

1 Introduction

On January 15, 2009, a US Airways Airbus A320-214 aircraft made a forced landing (technically, ditching) in the Hudson River in New York. It resulted in the total loss of the aircraft but did not lead to any human loss (Nóbrega, 2014). It was speculated after the event that the pilots were informed by the airport controllers from La Guardia (LGA), where they took off, during the emergency that they had been facing before they made the decision to land on the river, that an alternative to the emergency landing would be the Teterboro Airport (TEB). However, when the most experienced pilot viewed the tower of the Teterboro Airport "rising" from his perspective through the plane's windshield, he concluded that they would not have arrived at the airport while gliding. The best decision was to land on the Hudson River.

This decision was based on a well-known heuristic (*Heuristic*, from the Greek heurikein, means using experience to learn and find practical and simple solutions to problems) in the theory of decision-making, the "gaze heuristic." In the analyses that occurred afterwards, as is common after aeronautical accidents where one tries to learn from the mistakes and successes of real situations, it was concluded that

[1] Divisão de Ensino, Academia da Força Aérea, Estrada de Aguaí, s/n, Campo Fontenelle, CEP 13643-000, Pirassununga, SP, Brasil, e-mail: lma28@uol.com.br; luizmauriciolmas@afa.aer.mil.br

[2] Programa de Pós-graduação em Ciências Aeroespaciais, Universidade da Força Aérea, Av. Marechal Fontenelle, 1000, Campo dos Afonsos, CEP 21740-002, Rio de Janeiro, RJ, Brasil

[3] Departamento de Engenharia de Biossistemas, Faculdade de Zootecnia e Engenharia de Alimentos, Universidade de São Paulo – USP, Av. Duque de Caxias Norte, 225, CEP 13635-900, Pirassununga, SP, Brasil, e-mail: rnunes@usp.br

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the rapid, efficient, and unambiguous communication between the pilots was the variable that weighed the heaviest in the success of the emergency operation. When the flight captain, who was not in the pilot position (in technical aviation language, PNF (*pilot not flying*)), found that birds had been sucked into the airplane turbines, he would have said in a clear and good tone: *my aircraft.* In other words, he would have applied another basic rule in aviation, which is respecting the authority of those in charge (Klein, 1998; Klein et al., 1993; Silva et al., 2009).

There are reports (Gigerenzer et al., 2011; Klein et al., 1993) of many other heuristics that have contributed substantially to several fields. These heuristics lead to positive effects, countering the ones that Kahneman & Tversky (1972 apud Gigerenzer & Brighton, 2009) elucidated, resulting in erroneous judgement. Moreover, they have been classified as an adaptive toolbox (Gigerenzer & Selten, 2001 apud Gigerenzer & Brighton, 2009). They are adaptive because they are considered valid within an ecosystem that is often characterized by high dynamism, a limited response time, and considerable risk, as is the case in aviation.

The main aim of this study is to start—and submit to future deepening discussion—to develop an inventory of heuristics that may be applied to the air instruction (instruction in all aspects of flying) that is provided to Brazilian Air Force Academy cadets (AFA-SP) as part of an instruction strategy that is based on adaptive behavior. In addition, this study aims to take the first step toward creating the most relevant latent variables (Pilati & Laros, 2007), highlighting the possible constructs of the basic instruction of air operations, *vis-à-vis* the heuristics already measured in the research on human judgment in dynamic situations and time constraints (Silva et al., 2009, 2013b). The study is characterized as a literature review focused on identifying latent variables (initial construct development) for the different stages of air instruction to be consolidated according to the identification of heuristics.

This study starts with a heuristic literature review (Klein, 2009; Gigerenzer et al., 2011), as well as the universally accepted functional classifications in air instruction (Merrit & Klinect, 2006). Subsequently, in view of the numerous heuristics already reported in the literature, those presenting the greatest potential for application in the Air Force Academy (AFA), will be discussed regardless of the needs of future advances. In the final sections, situations in which military aviation could benefit from these heuristics are discussed. This study is finalized with future conclusions and developments.

This study may also contribute to an ongoing research project at the AFA and the Air Force University of Rio de Janeiro (UNIFA-RJ), which aims to identify and assign weights to the most important variables in military pilot training (Silva et al., 2013a).

This study was influenced by the logic supporting the noblest conception of science, that is, the one that seeks to highlight new models, not merely replicate them.

2 The role of heuristics in decision-making training

2.1 Decision-making and heuristic theories

Decision-making theories may be classified as having normative, determining optimal rational decision properties, and positive, decribing the effectively performed decision-making processes that are present in multiple facets of everyday life.

Normative theories assume fully rational, perfectly informed individuals. Rationality is found in the compliance with some requirements related to a decision-maker's preferences such as transitivity (if alternative x is preferred over y, and y is preferred over z, then x will be preferred over z) and completeness (a decision-maker is able to assess all available alternatives), enabling the decision-maker to establish a full set of available alternatives. Some rational choice models include the continuity of preferences (if alternatives x and y are equivalent for a decision-maker, then it will always be possible to create an alternative z that is equivalent to x and y) to represent a decision-maker's objective through a continuous function, often called a utility function. The decision-maker's problem is to choose the alternative that optimizes the objective function, subject to one or more constraints. For instance, a consumer seeks greater well-being through the consumption of a basket of goods, constraining his choice to the baskets that may be acquired with his available wealth.

The rational choice theory was extended to situations in which the choice result is a random variable, generated by the expected value of the results and expected utility. The expected value is the sum of the possible values weighted according to their probability, such as mathematical expectation. The expected utility is a utility function (representing a decision-maker's preferences) weighted by the probability distribution of the arguments of the function. The decision-maker's attitude towards risk is represented by the utility function curvature: aversion (propensity, indifference) to risk is associated with concave utility functions (convex, linear ones).

Due to the rational choice theory assumptions, assessing a random alternative is neither affected when this alternative is compared to other possible choices, nor is it affected by the order in which the alternatives are presented. Furthermore, a decision-maker is capable of mapping and attributing odds to all choice alternatives.

The expected utility was successfully applied in several contexts, including finance, actuarial sciences, contract theory, and production management. Nevertheless, for a growing number of applications, this theory seemed incomplete and deficient in the sense that the verified behavior would be paradoxical according to the theory (Zurita, 2005). When making decisions, the agents repeatedly and consistently violate the rational choice assumptions. The theory does not explain how agents find solutions to the expected utility maximization problems, which may be particularly relevant in scarce information contexts and the limited time that is available for decision-making. The expected utility is not applied in choices under uncertainty, where an agent is neither able to assign probability, nor is he able to identify all possible relevant events according to Knight's (1921) classic distinction.

When attempting to replace the mathematical modeling and optimization algorithms, Herbert Simon (1957) found an alternative basis for the decision-making theory in limited rationality. Human beings have limitations in formulating and solving complex problems, as well as when processing information. However, they partially compensate for these deficiencies by recognizing patterns in the phenomena occurring in their environment. Rather than finding a solution to the choice problems through calculation, a limited rational agent develops search mechanisms for viable solutions; instead of finding optimal solutions, real decision-makers interrupt searches once they find satisfactory solutions.

By rejecting full rationality and necessarily optimal decisions, the alternative theory must indicate which decision-making rules are used by the agents. Simon introduced the concept of procedural rationality, focusing on how a decision was made, and being less interested in which decision was chosen. The choice process and the agent conducting this process strongly influence the decision result, which becomes even more evident in complex situations (Barros, 2010).

Tversky & Kahneman (1974) and Kahneman (2011) assumed that, in most decisions, the human mind resorts to heuristics or rules of thumb, which are highly economical in terms of their information and processing capacity. Furthermore, they are generally effective, despite being conducive to systematic, predictable judgment errors in some situations. A research program was commenced, and although it acknowledged the functional value of heuristic tools, it was almost completely focused on the research on bias and judgment failures (Fiedler & Von Sydow, 2015).

In contradiction to the expected utility prognostics, Tversky & Kahneman (1992) identified a risk-taking pattern, in which neither of the agents weighs the possible events by their respective probabilities, nor do they maintain a similar attitude towards risk. Thus, they established an asymmetry between losses and gains; unlikely events would be weighted more than proportionally per the respective probability. On the other hand, very likely events would be underestimated; agents would tend to be averse to the risk of gains, but prone to the risk of losses.

According to Vranas (2000), Gigerenzer argued that it may not be appropriate to characterize some of the biases identified by Tversky & Kahneman (1974) as errors or fallacies, especially in the judgment of particular cases in which the probabilistic rules would not make sense. Katsikopoulos & Gigerenzer (2008) found that some heuristics are related to the lexicographic order of choice criteria (similar to the order of entries in a dictionary). This generated more accurate estimates of empirical results than other choice models. Such heuristics violate the choice theory based on the expected utility but produce optimal or almost optimal decisions.

As mentioned by Kelman (2011), heuristic studies are dominated by two distinct perspectives. One emphasizes the judgment biases induced by certain heuristics, while the other highlights the positive role of heuristics in fostering a decision-maker's adaptation to his environment.

2.2 Heuristics in vocational training

The development of heuristics and the ability to judge the adequacy of certain heuristics for the problems faced in professional practice have received the attention of higher education in several areas. Talanquer (2014) noted that chemistry students often provide superficial solutions to proposed problems. They cease to acknowledge relevant information in their judgements, as well as decisions on chemical substances and processes properties, and precipitate generalizations. To improve the effectiveness of teaching, Talanquer (2014) identified a set of heuristics that could be at the root of learning failures.

Specifically, in contexts of limited information decisions, a severe time constraint on decision-making, and grave decision consequences, professional training in heuristics can favor professionals' adaptations to complex, changing environments. Corroborating common sense, there is abundant evidence that time constraints and complexity tend to raise the likelihood of judgment errors (e.g., Young et al., 2012).

Haburchak et al. (2008) recommended that the education and practical training of medical courses would foster heuristics in students. Not complying with them would produce poor diagnoses, false expectations, and unexpected and undesired results, as well as poor limited resources. For these authors, the rules underlying diagnosis and therapy have not been sufficiently studied. They suggest that health education should develop the perception and practical application of physical principles (finiteness, inertia, entropy, and uncertainty), and economic principles (diminishing returns, unintentional consequences, distribution, and the resource economy).

Roberts (2013) identified six heuristics that are beneficial to the nursing practice, concerning information processing and action planning. To detect the heuristics employed by students, the "thinking out loud" technique was used, in which a student verbalizes his thoughts as he performs a certain task, allowing the instructor to assess and then provide feedback on the decisions taken.

Bleakley et al. (2003) found that medical students and even experienced doctors tend to see in imaging test results exactly what they expected to find, based on anamnesis and physical examinations of patients, often missing relevant information. To reduce this bias, the authors propose exercises in the field of visual arts that would facilitate the passage from a superficial to a detailed view in imaging diagnoses.

Finding that many medical decisions are made in an uncertainty environment, Elstein (1999) proposes that the choice criterion should maximize the expected utility. The right decision, based on the available information on the odds of the different likely results, would serve as a standard to evaluate doctors' choices.

In this perspective, the author describes and explains some well-documented judgment errors, which would result from inadequate, biased heuristics. For example, Elstein (1999) presented a study on the prescription of hormone replacement drugs that found that doctors tended to underestimate the risks resulting from fractures and overestimate the risks of breast and uterus cancer. According to the expected utility criterion, they did not recommend hormone replacement therapy in cases where this would be the expected outcome.

3 Heuristics as adaptation tools in air education

Air education is offered at the AFA in basic and advanced stages. Basic air education is offered to young people from an age group where the neocortex is perhaps not fully developed. For this reason, it is believed that weights must be allocated to the most relevant variables (Silva et al., 2013a), and possible constructs of basic air operations must be highlighted, vis-à-vis the heuristics already tested, producing satisfactory results (Gigerenzer et al., 2011) even in different areas.

Herbert E. Simon was one of the most devoted authors on decision-making and artificial intelligence theories. He won the Nobel Prize in economics and championed the need to understand that, more important than arguing whether it is the mind or the environment that should come first in a decision, what matters is "[…] the finding that both the mind and the environment are like two blades of the same pair of scissors" (Gigerenzer et al., 2011, p. xvii). It is impossible to say which one contributed to a given paper cut the most. This means that the use of reason only makes sense if one considers the environment *pari passu,* or the ecosystem where the decision must be made. Thus, a decision cannot only be logical or ecosystem-related; it is recommended that decisions are based on (eco)logical devices (Vianna, 1989; Silva, 2000).

General aviation practice, as well as military flight training, is involved in a rather complex and diversified ecosystem of the involved agents. In military aviation, there are the aircrafts and their pilots; nevertheless, as important as aircrafts and pilots are, complex interactions take place among pilots, aircraft and their command and control, logistics, and maintenance systems.

In civil aviation, the complexity is not lessened, and it may even be increased because not only are there aircrafts and pilots, but there are also airline companies operating the aircraft, the flight controllers in different airspaces (national and international), the ground staff (from the airline companies and airports), and regulatory bodies such as the National Civil Aviation Agency (ANAC). When it comes to aircraft safely flying in a controlled airspace, we are confronted with an ecosystem where its agents make complex decisions in real situations and with severe decision time limitations (Silva et al., 2009, 2013a).

In this way, identifying decision methods inspired by Simon's scissors metaphor, which may be classified as hybrids (Vianna, 1989; Silva, 2000), has extreme validity in aviation. Air navigation is a practice in an ecosystem in which it cannot be said that a pilot, while controlling his aircraft, is using either one of the scissor blades.

Furthermore, because it is involved in a dynamic, risky system in which there may be limited decision-making time, a pilot must develop a great deal of skill—normally acquired after many hours of experience—to select the most relevant information in each navigation stage. The desired adaptive mind would be able to make decisions with less, not more, information (Gigerenzer et al., 2011).

Since agents must manage multiple tasks, they are expected to be aware of the relative weight of each of the variables involved in the decisions, which are usually quick and made in a dynamic environment, with little available response time.

Questions concerning risk perception, already examined in previous studies, have pointed out elements of the prospective theory as having high potential for implementation in the operating environment of the AFA (Silva, 2013). In addition, it also contained aspects such as multiple tasks management and the influence of impulsivity, self-control, and sports practice (Moura, 2016 – not published, submitted).

By seeking a more detailed understanding of the variables involved in the AFA air instruction, and consequently, reaching an operational definition (constructs) of air operations in basic air education, there will be an increased flow of communication between instructors and students. This will also contribute to the improvement of air safety in this institution. Therefore, this aim will initially be sought by selecting lexicographic heuristics with hypothetical applications in the aviation arena.

Gigerenzer et al. (2011, p. 17) present a summary table with ten heuristics deemed "well studied", on which there is evidence of efficiency. Six were selected, with hypothetical examples illustrating their aviation applications.

1. *Recognition Heuristic* (Goldstein & Gigerenzer, 2002 apud Gigerenzer et al., 2011).

Definition: If one of two alternatives is more easily recognized, infer that it has the higher value as choice criterion.

Aviation example: If between two airports Guarulhos (SP) and Confins (MG), the pilot recognizes the Guarulhos airport more easily, the Guarulhos airport is likely larger in terms of aeronautical infrastructure than the Confins airport. This information may be very important, for example, to decide whether or not to enter controlled spaces without any specific guidance on the minimum requirements needed for such a procedure.

2. *Fluency Heuristics* (Jacoby & Dallas, 1981 apud Gigerenzer et al., 2011).

Definition: If both alternatives are recognized, but one is recognized more quickly than the other, infer that it has higher value in the choice criterion.

Aviation example: If a pilot, facing an emergency due to a communication failure, must know which one of two airports has an instrument approach system, he must infer that the airport remembered more quickly is likely the airport with the best aeronautical infrastructure.

3. *Count Heuristics* (Dawes, 1979 apud Gigerenzer et al., 2011).

Definition: To estimate a choice criterion, do not seek to estimate criteria weights, but count the number of positive cues in each choice criterion only.

Aviation example: A pilot has perceived engine failures in flight. While trying to identify the causes of the engine problem, he could simply count the number of positive cues for each possible cause. Furthermore, oil pressure loss and a sharp increase in engine temperature are unambiguous cues of a motor stop prognosis.

4. *Automatic selection heuristics (default)* (Johnson & Goldstein, 2003; Pichert & Katsikopoulos, 2008 apud Gigerenzer et al., 2011).

Definition: If there is a default, do nothing about it. Follow the predicted steps.

Aviation example: If you are in a recurrent emergency situation that was practiced in simulated training, follow either the checklist (Gawande, 2010) or the foreseen steps in the aircraft operation manuals.

5. *Imitate the majority heuristic* (Boyd & Richerson, 2005 apud Gigerenzer et al., 2011).

Definition: look at the majority of people in the peer group and imitate their behavior.

Aviation example: A pilot approaching land at a non-controlled airport, without visual contact with the windsock indicating the direction of the wind, would request by radio frequency which landing strip is being used by other pilots.

6. *Successful heuristic* (Boyd & Richerson, 2005 apud Gigerenzer et al., 2011).

Definition: Determine the most successful agents and imitate their behavior.

Aviation example: A newly qualified pilot facing an adverse situation could wonder: what would my instructor do in this situation?

Let us consider the universally accepted functional classifications in air instruction, such as viewing the sensitive points of an AFA adaptive toolbox, and, equally important, the beginning of a heuristic inventory for basic air instruction.

According to O'Hare (1992), there are five critical pilot behaviors that may be developed from the beginning of instruction and pose a threat to air operation safety. They are: (i) the "macho" syndrome; (ii) a feeling of invulnerability; (iii) resignation; (iv) impulsivity; and (v) anti-authoritarianism. In the macho syndrome, pilots, especially the less experienced ones, reveal a tendency to take risks that is greater than what would be prudent in aviation, given their own limits. The feeling of invulnerability would be an antidote to the necessary dedication that they must show to their studies and careful air operation planning. Resignation would act in the opposite direction of more immediate corrective actions. Impulsivity, which in the past may have even been a factor conducive to the military aviation feats of fearless warriors, is today one of the main causes of accidents. Finally, anti-authoritarianism, would be a resistance to accepting the division of responsibilities, whether in relations among members of the same crew or in obeying air traffic rules and regulations. Thus, a first step towards the AFA adaptive toolbox would be the intensive training of cadets as an antidote to such critical behaviors.

Perhaps the most crucial point is the consolidated trinomial (Kaempf & Klein, 1994*)*: *Aviate, Navigate, and Communicate*. In other words, a pilot undergoing training must understand, as soon as possible, that the order of priorities of his decisions must carefully follow, in the hierarchical order of appearance, the three different actions of the trinomial. Above all, a pilot must have as the primary command of his attention the maintenance of basic air navigation behaviors *(Aviate)* to ensure that the aircraft continues to fly well. This includes controlling parameters such as altitude, speed, horizontal plane stability, and controlling engine-operating parameters. Johnston et al. (1994) also emphasize the different flight phases such as taxiing, takeoff, leveling, approach, and landing.

All necessary efforts are expected to be made to meet the air navigation requirements (*Aviation*). After that, a pilot should focus on actions related to the navigation of the aircraft (*Navigate*). This includes at least one point of origin and destination, which in turn implies maintaining the heading, the minimum distance of the terrain obstacles, and the controlled flight time.

The previously mentioned conditions are to be met. Only then should the pilot focus his attention on communication requirements, including radio frequency adjustments, respecting the flight rules (either visually or via instruments), and verbal communication with control bodies or other flying aircraft nearby. In a non-exhaustive way, these are the main functional classifications in air instruction.

Basic instruction is given at the AFA in the second of the four grades of the course. It is carried out in single-engine airplanes that are propelled by internal combustion engines. Henceforth, this instruction will be referred to as the second Instructional Flying Squadron (2º EIA). Advanced instruction is provided in the fourth grade and is carried out in single-engine airplanes that are propelled by reaction engines. In this study, only the second EIA instruction is being considered.

The main investigations already carried out in the ongoing research project at the AFA and the UNIFA-RJ (Pereira & Silva, 2015; Silva et al., 2009, 2013b) were carried out with cadet samples that were already submitted to the second EIA. This air instruction is provided to young people (21 years of age on average) who have not accrued many flight hours. Moreover, as mentioned earlier, their *neocortices* may not have achieved proper maturity for adequate cognition and the use of reason. They may not be mature enough for the use of intuition either, since they do not have sufficient experience to do so (Gigerenzer, 2009; Klein, 2009).

Our study focuses on a sample of pilots who do not have much experience yet, and comprises several questions, including the fact that the cues to identify abnormal events in general are presented in a very salient way.

Merrit & Klinect (2006) emphasize that a distinction between threats and errors in pilot training must be made. The threats come from the external environment, which is outside the influence of pilots. The most common types are adverse weather conditions, airports with poor infrastructure, communication problems with air traffic control bodies, and distractions that may occur on the flight deck. On the other hand, errors are made by the crew. They are related to aircraft automation, flight controls, taxi procedures, and other ground procedures, as well as incorrect reading of and typing on the onboard systems.

The same authors emphasize that the main orientation that should be provided to mitigate threats and errors would be, initially, the development of resilience capacity. Herein, resilience would be redirecting an aircraft to its normal parameters (*Aviation*). Furthermore, to succeed in this type of training, Merrit & Klinect (2006) suggest the following sequence for instructions programs:

- Anticipation;
- Recognition;
- Recovery.

Situational awareness training techniques are applied in the Anticipation program (Endsley et al., 2003). In addition to some of the previously mentioned heuristics, meta-cognition training is suggested for the Recognition program. Simulation-based learning programs are suggested for the Recovery program and are based on errors that have already been found in aircraft accidents and incidents.

Authors Merrit & Klinect (2006) recommend that there should be no attempt to build systems capable of avoiding errors. Rather, they should highlight why or where they make mistakes for the decision-makers. Thus, errors will not be repeated. They also state that the correct operation of systems is due to specific configurations, scales, and selected cultures.

Finally, considering the relevant propositions for the AFA, "mental flexibility" and "intellectual adaptability" are recommended in aviation cognitive training.

4 Conclusions and future developments

This article contributes to identifying and allocating weights to relevant variables in military pilot training, as well as to a wider discussion, which concerns the "bias-variance" dilemma (Gigerenzer et al., 2011). In the "bias-variance" dilemma, either the level or the amount of information required for a good decision is highlighted when an assessment of a more relevant information selection strategy is sought. Such a discussion is based on the worldview of the scientific method practitioners. Those who are more prone to controlled experiments in laboratories would be framed in a sort of *"small world,"* which is free of uncertainties and adequately modeled by statistics. On the other hand, those who are less prone to controlled experiments in laboratories (Silva et al., 2009) would be framed in a sort of "*large world*", which is full of uncertainties and is dynamic and difficult to model.

In the "*small world*", statistics would be sufficient; hence, the most immediate adverse effect of this world would be the problem of variance and the necessary criteria to control it. In the "*large world*", the heuristics would be sufficient; hence, the most immediate adverse effect of this world would be the problem of bias in human judgment.

However, in this paradox, applied to situations where decision-making time is scarce and the consequences may be fatal, heuristics would have a certain advantage over statistics. For heuristics, less information, not more, would be better (in contrast to what is usually required in statistical terms). In order to illustrate this confrontation, there is a tragic example, which is the accident of an Airbus A330-200 aircraft that was flying the Rio de Janeiro-Paris route, and crashed in the Atlantic Ocean in 2009, killing everyone on board. In this accident, had the pilots paid attention to less information, they might have been successful in avoiding a fatal accident. Something like the recognition heuristic (heuristic 1), presented in the previous section of this paper would have been useful. In the case of this accident, the recognition heuristic would be applied in selecting the most relevant information to maintain a flight in normal situations, despite mechanical failures.

The least experienced pilots, such as our cadets, generally spend more time searching for information. This extra time consumption may be a contributing factor to the resulting spiral of uncertainties and may increase the risk of air operations. Another characteristic of less experienced pilots is that they tend to focus their attention on the most prominent information, which may or may not be the most important, depending on each particular situation. It is aggravating that abnormal situations usually present clues of little or no salience.

Thus, since the least experienced cadets are not yet fully "equipped" with the tools needed to face the most varied of situations, they must be provided with adequate training not only in the standard procedures envisaged for each operation, but also in terms of decision-support tools. In the specific case of aviation, simulators emerge as the best tool, as well as specific training in decision-making. The decision-making process requires mastery in meta-cognition, cognition of the cognition itself. Experienced pilots spontaneously develop effective heuristics through professional exercise, but they could also benefit from a systematic reflection on the decision-making process, since the processes of the establishment and mobilization of heuristics are dynamic. A critical assessment of decisions made by oneself or others is an important part of a pilot's continuing training. This activity may be facilitated and formalized by a systematic description of the heuristics mobilized in each specific case. In addition, the development of metacognition competences could facilitate the transmission of knowledge acquired among groups with various levels of experience.

The desired meta-cognition for our cadets is founded on two aspects. The first is situational awareness (Endsley et al., 2003), and the second is the different criteria for identification and risk-taking through mind maps.

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