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Learning from Errors: Cognition, Emotions and Safety Culture in the Italian Air Force

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Abstract

Learning from errors is essential to ensuring organizational safety and improving levels of performance. We consider the interaction between cognition, emotions, and safety culture in the context of a field study on learning from errors in the Italian Air Force. We find that errors often stem from sequential action chains that are concealed in habitual behavior and that become visible only when unforeseen circumstances occur. Furthermore, cognitive appraisal of risky situations triggers emotions of variable intensity that, when rationalized retrospectively, promote the internalization of lessons learned. Finally, cognitive and emotional experiences of errors are grounded in the broader safety culture of an organization, which provides a supportive context for error reporting and encourages the sharing of information and knowledge about error experiences. The analysis further suggests that cognition, emotion, and safety culture interact through sensemaking processes that inform the construction of errors and affect learning outcomes.

Keywords

cognition, emotions, learning from errors, safety culture, sensemaking

Introduction

Learning from errors is a fundamental requirement for all organizations, particularly for those operating in high-risk environments. It commonly denotes an effortful activity through which individuals reflect on errors they have made, understand their causes, and develop new knowledge that can be applied to future decisions and actions (Reason, 1990; Zhao, 2011). Several scholars have pointed out that learning from errors allows organizations to improve safety, reliability, and resilience (e.g., Reason, 1997; Ron, Lipshitz, & Popper, 2006; Weick, 1987; Weick & Sutcliffe, 2007).

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Others have highlighted phenomena of learning myopia and cognitive biases that may distort human judgment, especially under conditions of uncertainty (March & Levinthal, 1993; Perrow, 1999; Sagan, 1993; Tversky & Kahneman, 1974). Most organizational learning theories have focused on the cognitive dimension of errors, which emphasizes processes of acquisition, distribution, storage, retrieval, and interpretation of information supporting human decision processes (Huber, 1991; Walsh & Ungson, 1991). From this perspective, learning from errors depends on the organizational ability to gather and analyze relevant information regarding risk conditions, while failure is often associated with various forms of information deficit.

While cognitive theories have significantly advanced our understanding of managing errors in organizations that face trying conditions, these theories have been criticized for portraying individuals as emotion-free actors who address problematic situations by processing information within the limits imposed by their bounded rationality. Furthermore, little attention has so far been paid to the social construction of errors, i.e., the ways individuals in organizations sense, imagine, and interpret errors and how shared meanings attributed to errors affect learning processes (Gephart, van Maanen, & Oberlechner, 2009). These considerations underline two important gaps in current theories of learning from errors.

The first relates to the emotions associated with learning processes. There is a high degree of emotional content inherent in the execution of risky tasks, such as those characterizing organizations that operate in extreme environments. This refers to anticipatory feelings of anxiety, fear, and, more generally, representation of issues of life and death. Furthermore, errors carry important emotional consequences related to problems of individual responsibility, such as blame attribution and management, face saving, and decrease of self-esteem (Brown, Dutton, & Cook, 2001; Patriotta, 2003a). Cognitive learning from errors therefore requires a parallel emotional acceptance of the error itself. Second, the emotional acceptance of one's mistakes does not depend exclusively on the psychological characteristics of an individual, but is grounded in the specific safety culture of an organization. Our interest in safety culture stems from its close connection with empirical phenomena linked to errors, risk, and blame. Anthropological work suggests that errors are constructed within cultural frameworks which give them meaning (Douglas, 1992). From this perspective, institutionalized belief systems and sociocultural attitudes—as manifested in hierarchical relationships, lines of communication, incentives, and sanctions—significantly affect the perception of errors and the blaming patterns in organizational settings. In particular, the presence of a blame culture and the fear of disciplinary measures can provide a strong deterrent to the reporting of incidents and therefore inhibit learning from errors (Abramson & Senyshyn, 2010; Avery & Ivancevich, 1980).

The above analysis suggests that the connection of cognition, emotions, and culture is critical for understanding processes of organizational learning from errors. This connection has remained thus far poorly understood and conceptually underdeveloped. Accordingly, this paper addresses the following research question: How does the interaction of cognition, emotions, and safety culture influence the detection, reporting, and analysis of errors in organizational settings?

We investigate this question through an in-depth case study of learning from errors in the Italian Air Force (ITAF). In the past twenty years this organization has developed specific management practices aimed at simultaneously tackling problems of error, risk, and blame. This has been supported by the implementation of a "just culture" (Dekker, 2007; Reason, 1997) according to which pilots are not sanctioned for unsafe acts, such as involuntary errors, incurred during flight operations. Our findings reinforce the importance of cognition in processes of detection, analysis, and correction of errors. In our study, this was apparent in pilot accounts of the interaction between routine and mindful processes during flight missions and how this shaped their understanding of

risky situations. However, we also found that cognitive appraisal of risky situations triggered emotions of variable intensity that, when rationalized retrospectively, promoted the pilots' internalization of lessons learned. Finally, learning from errors was grounded in a broader cultural system that influenced the pilots' cognitive and emotional coping with flight missions and encouraged them to report, and reflect on, adverse events. Our study further suggests that cognition, emotion, and safety culture interact through sensemaking processes that support the construction of errors and affect learning outcomes.

In the next section, we review the relevant literature on learning from errors with a focus on cognitive, emotional, and cultural dimensions. We then describe our research design, methods of data collection, and approach to data analysis. In the empirical section, we first describe the ITAF pilots' core activities in some detail and then investigate how cognition, emotions, and safety values influence the pilots' perceptions of learning from errors. Finally, we discuss the main findings of our study and highlight their implications for understanding of learning from errors in organizational settings.

Learning from Errors: Theoretical Domain

Previous research on organizational learning from errors has been informed by a cognitive bias, which has fostered the investigation of how different aspects of information processing—such as information acquisition, distribution, interpretation, and retention—affect processes of learning from errors. The focus on cognition has produced important contributions, but it has not fully explored the role of emotions and culture. Namely, scholars privileging a cognitive view of learning from errors (1) have considered emotions only in negative terms, as a barrier to information processing, and (2) have often underestimated the influence of cultural values, belief systems, and collective attitudes on processes of error detection and reporting. To address these gaps, we consider three different, but strictly linked, dimensions of learning from errors: cognition, emotion, and culture.

The cognitive dimension

Cognition refers to the mental processes involved in gaining knowledge and comprehension, including aspects such as awareness, perception, reasoning, memory, and judgment. From a cognitive perspective, learning is the process of modifying one's interpretations of events and actions and thereby changing the range of one's potential behaviors (Fiol & Lyles, 1985; Huber, 1991). Several scholars have acknowledged that learning from experience is driven primarily by errors and failures, which trigger various forms of search and information processing (Lipshitz & Barak, 1995; March, 1994; Ron et al., 2006). According to Argyris and Schön (1996), learning occurs when errors—conceived as a mismatch between intentions and consequences—are detected, corrected, and removed. Specifically, learning involves the appraisal of errors against an existing cognitive frame that governs how individuals interpret situations and how they design and implement their actions.

A number of scholars have investigated learning from errors in the context of accident prevention and organizational safety (Leveson, Dulac, Marais, & Carroll, 2009; Perrow, 1999; Reason, 1997, 2008; Sagan, 1993; Turner, 1978; Vaughan, 1996). Wilensky (1967) uses the terms "information pathologies" and "intelligence failures" to denote the various deficiencies and inadequacies of organizational information processing (Scholl, 1999). Conversely, "organizational intelligence" refers to the capacity of an organization to obtain and elaborate clear and reliable information,

which supports the organization's ability to make sense of complex situations and act effectively. This is consistent with the view that organizational learning responds to acknowledged problems of analyzing and reflecting upon the sources of failure and drawing causal inferences (Mahler & Casamayou, 2009). By and large, cognitive theories of learning assume that lack of information reduces the range of possible courses of action, limits the evaluation of their consequences, and forces agents into errors. From this perspective, errors result from a gap between information and interpretation, i.e., between the availability of information and the ability to make sense of it.

The influence of sensemaking on learning processes has been addressed by scholars interested in risk and crisis management (Gephart, 1993, 1997; Shrivastava, Mitroff, Miller, & Miglani, 1988; Weick, 1988). Insights from this line of research have been fruitfully applied to increase safety conditions in high-risk organizational contexts and to design high reliability organizations (HROs) (LaPorte & Consolini, 1994; Roberts, 1990; Rochlin, 1993; Weick & Sutcliffe, 2007; Weick, Sutcliffe, & Obstfeld, 1999). HRO researchers maintain that overlooking signals of danger may be prevented through mindful organizing, that is, the development of cognitive and organizational systems that support situational awareness in the face of a plethora of diverse signals coming from the external environment (Weick et al., 1999, p. 88). Mindful organizing promotes active forms of information processing by which individuals in organizations develop a discriminatory capacity for noticing details and maintain attention to what is going on (Langer, 1989). According to Weick and Sutcliffe (2007, p. 9), "HROs encourage reporting errors, they elaborate experiences of near miss for what can be learned, and they are wary of the potential liabilities of success, including complacency, the temptation to reduce margins of safety, and the drift into automatic processing."

Research shows that people need to feel safe to report incidents or they will ignore them or cover them up (Edmondson, 1999; Reason, 1997; Tucker & Edmondson, 2003; Weick & Sutcliffe, 2007). To this end, HROs go beyond the simple "blame the operator" intepretations and favor the creation of "safe areas" with anonymous systems for reporting errors and near misses (Grabowski & Roberts, 1997; Haunschild & Sullivan, 2002). Furthermore, managerial practices such as encouraging people to ask questions and rewarding people who report errors strengthen an organization-wide culture that values reporting (Weick & Sutcliffe, 2007, p. 50). These latter considerations emphasize the role of emotional coping with errors and the cultural frameworks within which learning from errors occurs. In the next section we focus on these two further dimensions of learning from errors.

The emotional dimension

Emotions refer to fairly brief but intense experiences elicited by a particular target or cause, which often include physiological reactions and action sequences (Barsade & Gibson, 2007; Frijda, 1986; Lazarus, 1991). There is a widespread recognition that emotions are an essential aspect of work and organizational life (e.g., Ashkanasy, Zerbe, & Härtel, 2002; Elster, 1999; Fineman, 1993; Maitlis & Ozcelik, 2004). Less attention has been devoted to the interplay between emotion and learning in organizational settings, although there is a growing interest in engaging with this problem, as suggested by recent literature (Antonacopoulou & Gabriel, 2001; Fineman, 1997; Scherer & Tran, 2001; Simpson & Marshall, 2010; Vince, 2002). Several scholars have pointed out that work on organizational learning has been primarily conducted within a cognitively orientated domain, with little concern for the role of emotion. In particular, cognitive theories of organizational learning have tended to regard emotion as a barrier to rationality and information-processing activities (Simpson & Marshall, 2010). In this sense, cognition and emotion have been largely

treated as antithetic concepts, with the latter being seen as "uncomfortable knowledge," often getting in the way of effective accomplishment of tasks, and prompting organizational members to rationalize their feelings in terms of organizational goals and management purpose (Albrow, 1992; Fineman, 1993; Vince & Saleem, 2004).

Critics of this neglect of emotions in organizations have argued that the opposition between emotion and rationality is simplistic and that emotionality and rationality are interpenetrated (Ashforth & Humphrey, 1995). In particular, emotions provide an essential readout on our state of being as we act or learn and thereby inform processes of reflection in action (Fineman, 1997, p. 14). Emotional processes are particularly salient in the context of learning from errors (Zhao, 2011). As Hareli, Shomrat and Biger (2005) have pointed out, the experience of failure, whether real or imagined, is a significant event for the self (Brown et al., 2001) and a potent trigger of emotions (Frijda, 1986; Higgins, 1987; Lazarus, 1991; Ortony, Clore, & Collins, 1988; Tangney, Miller, Flicker, & Barlow, 1996). These emotions are expected to affect one's choice of how to deal with an undesirable situation and learn from it. Based on the existing literature we consider three important aspects of emotions associated with learning from errors: timing, valence, and intensity.

Timing refers to the temporal occurrence of emotions with respect to errors. In particular, anticipatory emotions denote "immediate visceral reactions (fear, anxiety, dread) to risk and uncertainties" (Lowenstein, Weber, Hsee, & Welch, 2001, pp. 267–8). Post-hoc emotions relate to the feelings arising from the reporting of errors and near misses. The first aspect emphasizes the instinctual and biological foundations of emotions (Ekman, 1992; Izard, 1977) and treats them as antecedent states that affect subsequent learning processes (Scherer & Tran, 2001). For example, failure to control emotions may lead to panic reactions; this, in turn, will make individuals and groups revert to primitive tendencies and impair their ability to make sense of and deal with critical situations (Weick, 1993). On the positive side, anticipatory emotions might affect how individuals prepare for risky tasks and maintain alertness in the face of potential failure (Weick & Sutcliffe, 2007). The second aspect portrays emotions as socially learned and culturally specific displays built around shared codes of meaning (Hochschild, 1979). For example, post-hoc emotions experienced by an individual or group involved in an organizational failure are significantly shaped by the cultural values promoted by the organization with respect to error reporting and blame attribution. In other words, culture affects the emotional climate of a collective (Scherer & Tran, 2001).

Emotional valence refers to the emotional evaluation ("positive" or "negative") of particular events, objects, or situations. Research on human error indicates that experiencing errors is unpleasant and can cause negative feelings, including fear, guilt, and shame (Zhao & Olivera, 2006). This can, in turn, affect processes of judgment and decision-making. Furthermore, negative emotions are most noticeable, among other things, because negative events represent a threat to our well-being (Ben-Ze'ev, 2001). Finally, emotional intensity refers to the strength with which an emotion manifests itself, and it ranges from "low" to "high." There is evidence that negative stimuli (such as errors) are, on average, experienced as more intense emotionally than positive stimuli (Ito, Larsen, Smith, & Cacioppo, 1998). Errors trigger intense (negative) emotions, which are likely to affect individual learning experiences.

In sum, emotions interfere in important ways with information processing and rationality. As Fineman (1997, p. 16) put it, "we have feelings about what we think and thoughts about what we feel." This interaction can either enable or constrain the effective accomplishment of organizational tasks and it is therefore critically associated with processes of learning from errors. Furthermore, emotions are socially constructed and subject to cultural norms. In particular, organizational cultures "provide beliefs about emotional states, a vocabulary for discussing them, and a set of socially accepted attributions for the states" (Ashforth & Humphrey, 1995, p. 100).

The cultural dimension

Organizational culture denotes the set of values, beliefs, and expectations that members of a given group come to share at a given time (Pettigrew, 1979). Through a sharing of patterns of meaning, culture provides a fundamental sensemaking resource that guides members' interpretations in the face of problematic situations and ultimately affect an organization's ability to learn (Cook & Yanow, 2006; Siehl & Martin, 1990). Culture influences the social construction of errors both in terms of seeing risk and in terms of apportioning responsibility and blame (Hutter, 2005). In particular, culture is significantly linked to the institutional dilemma of blame, i.e., the policy of an organization with respect to individual accountability in case of errors, including how errors ought to be managed and who should be blamed (Catino, 2008; Gherardi, 2004; Reason, 1997; Sagan, 1993). This represents a dilemma because organizations face a trade-off between blaming people for unsafe acts and learning from such acts.

Barriers to learning are strongly influenced by the specific safety culture of an organization, that is, the attitudes, beliefs, perceptions, and values that employees share in relation to safety (Cox & Cox, 1991). These values determine the commitment to, and the style and proficiency of, an organization's health and safety management (Reason, 1997). This points out the opposition between "blame culture" and "just culture" (Catino, 2008; Dekker, 2007). A blame culture considers errors mainly as an indication of professional incapacity or negligence. Individuals in organizations may be reluctant to report negative information, especially when this can lead to disciplinary sanctions, or result in being blamed or ridiculed because of an error (Edmondson, 1999). For example, it can be very difficult for doctors to report errors because of concerns regarding legal consequences (e.g., insurance liabilities) as well as fear of losing face vis-a-vis their colleagues. A blame culture is therefore likely to block negative feedback and hamper an organization's ability to detect and correct errors.

A just culture, on the other hand, is about supporting people who are willing to report. Within a just culture, frontline operators or others are not punished for actions, omissions, or decisions taken by them that are commensurate with their experience and training. However, gross negligence, willful violations, and destructive acts are not tolerated (Eurocontrol, 2006). Reason (1997, p. 195) describes just culture as "an atmosphere of trust in which people are encouraged, even rewarded for providing essential safety-related information—but in which they are clear about where the line must be drawn between acceptable and unacceptable behavior." A just culture organization is aware that a culture of safety crucially requires the creation of an open, free, non-punitive environment in which people can feel safe to report adverse events and near misses. Conversely, "practices of blaming create an atmosphere that tends to stigmatize people and discourage them from speaking up" (Weick & Sutcliffe, 2007, p. 132). Ruitenberg (2002) cited a 50 percent drop in incident reports after the prosecution of air traffic controllers involved in a near miss.

It is important to stress that equating blame-free systems with an absence of personal accountability is erroneous (Dekker, 2007). In a just culture, staff can differentiate between acceptable and unacceptable acts (Ferguson & Fakelmann, 2005). The complexity of the balance between accountability and learning is well explained by Ron, Lipshitz, and Popper in their study of how Israeli military pilots learn from errors: "Managing the tension [between accountability and learning] is helped by pilots' recognitions that flying is hazardous and, without a disciplinary framework, there are bound to be crashes, and by the fact that the core values of the debriefing culture are truthful reporting, public accountability, the ability to admit error, and getting—making the most of—an opportunity to learn" (Ron et al., 2006, p. 1078).

Based on the above theoretical discussion, we note that the existing literature has considered, to a variable degree, the influence of cognitive, emotional, and cultural dimensions on learning from errors. However, the patterns of interaction by which these three dimensions affect learning from errors have remained so far understudied. In the remainder of the paper, we explore the connection between cognitive, emotional, and cultural learning in the setting of the ITAF.

Research Design and Methods

Data collection

Fieldwork was carried out between 2008 and 2009 in two bases of the ITAF. Additional fieldwork was conducted in 2011 at the ITAF headquarters in Rome. Our sampling procedure was theory-driven. Given our interest in pilots' learning from errors, we selected air bases as operational sites in which pilots conducted their activity and experienced cases of errors and mishaps. Our key informants at the ITAF granted access to two air bases characterized by homogenous features in terms of organizational structure and culture, technology, personnel composition, pilots' activities, and overall performance. The homogeneous characteristics of the selected sites allowed us to maximize the size of the sample while controlling for variations in how cognition, emotion, and safety culture influenced pilots' learning from errors. Data collection relied on three main sources:

1. Qualitative interviews;
2. Analysis of flight mishap cases reported in *Sicurezza Volo* ("*SV*"), the ITAF's flight safety magazine;
3. Observation of briefing and debriefing sessions.

Interviews. We conducted 37 formal interviews. Our sample included 27 pilots selected in consultation with the squadron commander of each air base to represent different levels of experience and age. The selected pilots were aged between 28 and 42 years old, with 8 to 20 years of service, and with 350 to over 1,000 flight hours. In addition, we interviewed the squadron commanders of the selected air bases (2), the chief safety inspectors of the selected air bases (2), the two generals who initiated the ITAF's flight safety program in 1991, and four colonels from the ITAF's Flight Safety Inspectorate who had previously been involved in safety programs at the selected air bases. Interviews were conducted in Italian. Each interview lasted about one hour. Senior figures were interviewed several times over the duration of the study and at greater length. Overall the duration of interviews totaled over 60 hours. All the interviews were tape-recorded and transcribed. Furthermore, we had several informal conversations with other operators at the selected air force bases and at the ITAF's Flight Safety Inspectorate. These talks were aimed at obtaining additional information regarding the error reporting system and to gain feedback on emerging research findings.

Analysis of flight mishap cases published in SV, the ITAF's house magazine. We analyzed 70 cases of flight mishaps published in the ITAF's house magazine *SV*. The magazine aims to increase the professional training of pilots and ITAF members in order to prevent flight accidents and other events that might hinder the operational capacity of the Air Force. In each issue of this magazine, a pilot reports a flight mishap case and draws some lessons from it. The cases can be either real or fictitious and they are designed for didactic purposes. They reflect the pilot's opinion on specific issues related to safety and learning from errors. For this reason, the reported cases are particularly useful for understanding not only the phenomenology of the most common errors, but also how the pilots, and the organization more generally, are expected to cope with critical safety-related situations.

Observation of briefing and debriefing sessions. We observed four briefing (before flight mission) and debriefing (after flight mission) sessions in selected air bases. The observations were focused on: (1) understanding issues regarding flight safety; (2) understanding how pilots think about errors and near misses and how they try to learn from them; (3) detecting the communication style regarding errors among members of the aircrew. We took detailed notes and, when the briefing/debriefing ended, we talked to the pilots to clarify specific aspects of particularly salient issues. We also observed meetings, air force activities, seminars, training courses, and informal situations at the selected air force bases.

Our main data sources were complemented by the analysis of internal documents, including risk management reports, statistics on flight mishaps, and internal research into flight reliability. Through interviews, documents, and observation, we investigated the flow of activities defining the core task of pilots—namely briefing, flying missions, and debriefing. Within these activities we focused on processes related to learning from errors, such as error detection, correction and reporting. We collected stories related to errors and near misses and we analyzed how pilots reflected on those stories.

Data analysis. When analyzing our different data sources we relied on both deductive and inductive thinking to interpret and structure the meanings of our fieldwork. We started with a minimal conceptual framework defined by research questions and conceptual categories. Our conceptual framework presumed that cognitive, emotional, and cultural factors affected learning from errors, but it did not specify the ways in which such concepts would connect to each other. In other words, the conceptual framework defined a focus for the study and assumed a broad causal relationship, but it did not provide inferential patterns regarding the interaction between the variables involved. From this minimal conceptual framework we developed a coding system to classify interviews, case reports, and observations of briefing/debriefing sessions.

The balance among the three main conceptual categories informing our study shifted as fieldwork progressed. For example, we reviewed the literature on safety culture prior to entering the field because we expected to study phenomena related to shifts in attitudes towards errors induced by the introduction of just culture within a military organization. Given our research area of expertise, we were also "theoretically sensitive" (Strauss & Corbin, 1990) to the predominance of cognitive approaches to learning from errors in risky situations. As fieldwork continued, we became increasingly aware of the relevance of emotions in processes of learning from errors. Accordingly, we went back to the literature and looked at studies that had focused on the emotional implications of learning from errors. This also influenced subsequent data collection and analysis. For example, interviews initially followed a standard list of questions designed to elicit detailed information regarding the phenomenology of errors, the error reporting system, and the processes leading to organizational learning from errors. However, after the first set of interviews was conducted (about ten across bases) we added questions focused on the emotional aspect of learning from errors in our interview protocol and we included emotions as a main coding category for data analysis. The final set of interviews and observations was conducted during the revision stage of the research, after an advanced draft of the paper had been written and submitted for publication. It only contained four questions (concerning cognition, emotion, just culture, and Murphy's law) and it was intended to refine and validate the conceptual framework.

We treated all documents, interview transcripts, and notes from observations as texts, which we analyzed through line-by-line coding following the same coding system. Within the text, we first highlighted passages that featured cognitive, emotional, and cultural statements on learning from errors. We then assessed the presence and nature of linkages between cognition, emotion, and

safety culture in relation to learning from errors. Overall, the three sources provided an integrated database while being characterized by a variable degree of data structure. These characteristics affected the interpretive process and were particularly useful in conducting data triangulation. Articles published in *SV* were in the form of case studies and therefore were favorably structured for the analysis of learning from errors. They portrayed pre-organized narratives of errors and mishaps with a clear beginning, middle, and end. Furthermore, they reported the pilots' own reflections on the case (e.g., moral of the story and lessons learned). Interviews provided partially organized data in which the researchers asked the pilots to narrate stories according to a semi-structured interview protocol. The subsequent interpretation required a certain degree of data reduction prior to connecting relevant quotes to coding categories. We used the observations mainly to document in some detail the pilots' core activities and to provide contextual understanding of learning from error dynamics. In this regard, observations provided more descriptive and closer-to-action data in which interpretation and structuring emerged along the way through repeated observational sessions. Although we took detailed notes during the observation, the analytical strategy adopted for the interpretation of these notes followed the logic of thick description. Our aim was to provide a realist narrative of "pilots at work" (van Maanen, 1988).

Our coding system was structured according to three main types of code: descriptive, analytical, and pattern (Miles & Huberman, 1994), reflecting the logical steps of the interpretive process ranging from descriptive to inferential levels of analysis. *Descriptive codes* comprised the five conceptual categories driving the research. These included learning, error, cognition, culture, and emotions. We defined keywords associated with each code and developed a rudimentary list of semantic descriptors of those keywords. This allowed us to detect the presence of a given category in the text. We then expanded this original list through dictionary work and inductive reading of the data transcripts (e.g., by adding synonyms as well as other terms that were systematically deployed in the text to refer to a particular category). Table 1 shows the complete list of descriptors for the five categories as it has emerged from our analysis. With the help of this list of descriptors, we systematically coded all the sentences in the transcribed text according to the selected categories and keywords.

Drawing on the existing literature, we further specified the codes within each broad category (*analytical codes*). For example, we considered different types of information processing (routine/mindful); we classified emotions in terms of timing, valence, and intensity; we looked at selected aspects of organizational culture such as attitudes towards error and blame, and attitudes towards safety. The list of codes was progressively expanded through iterative readings of the data set. For example, we noted recurrent references to Murphy's law, which provided a key sensemaking resource to the pilots.

Subsequently, we developed inductive patterns and identified relationships between coded categories (*pattern codes*). For example, we considered the influence of emotional states on automatic/mindful processing, the link between emotional intensity and cognitive dynamics of collective remembering, and how Murphy's law underpinned cognitive, emotional, and cultural understanding of errors. From this analysis tentative relationships between variables began to emerge, which provided the building blocks for the development of a theoretical framework. The final analytical step involved moving from pattern codes to theory building (Eisenhardt, 1989). Through iterative and systematic comparison of the emergent framework with the case study evidence we assessed how well the theory fitted with case data. This led us to inductively develop a theoretical model interpreting and generalizing from the data. Figure 1 exemplifies the coding system developed for data analysis and linking descriptive, analytical, and pattern codes.

Table 1. Descriptive codes.

Category	Definition	Semantic descriptors
Learning	The acquisition of knowledge and skills that enable an individual or group to comprehend and navigate novel problems	After the fact; Analysis, Avoiding; Cause; Discussion, Effect; Experience; Feedback, Learning from errors; Lesson learned; Prevention; Revisiting; Reflection; Risk analysis, Sharing; Signal(ling), Simulation; Training
Error	An act involving an imprudent or unintentional deviation from a desired result.	Breakdown; Chain of events; Disruption; Unexpected; Error; Error anticipation; Error detection; Error reporting; Error correction; Failure; Focus; Honest error; Human error; Incident; Latent failure; Mishap; Mistake; Misunderstanding; Near miss; Repetition; Slip; Technical error; Violation
Cognition	The mental processes involved in gaining knowledge and comprehension, including aspects such as awareness, perception, reasoning, memory and judgment	Attention; (Situational) awareness; Alert(ness); Automatic; Clearing; Distraction; Familiar/unfamiliar; Information (processing); Lock out; Mechanical; Mindfulness; Mindlessness; Optical illusions; Memory; Perception; Rationality, Reasoning, Routine; Tunnel vision
Emotion	Fairly brief but intense experiences elicited by a particular target or cause, which often include physiological reactions and action sequences	Angst; Anxiety; Awe; Calmness; Chaos; Confusion; Courage; Danger; Disappointment; Distraction; Doubt; Emergency; Emotion; Enthusiasm; Fear; Guilt; Hesitation; Humbleness; Luck; Overconfidence; Pressure; Pride; Reaction; Reassuring; Risk; Scare; Self-Confidence; Sense of reward; Shame; Shivering; Sorry; Stress; Surprise; Uncertainty; Unease
(Safety) culture	The set of norms, values and beliefs shared by a particular group, with an emphasis on attitudes towards errors and blame	Attitudes; Authoritarian; Beliefs, Blame; Climate; Compliments; Conduct Conformity; Deviation; Discipline, Error reporting; Gratitude; Hierarchy; Just culture; Macho (culture); Motivation; Murphy's Law; Norms, Punishment; Resistance; Reward; Safety (awareness); Sense of duty, Social rules; Support from the top; Tradition, Trust; Values, Violation

Organizational Setting and Error Reporting

The Italian Air Force consists of 20 flight divisions employing about 1,000 pilots. Since 1991 the ITAF has developed a new organizational model for risk management and created a new organizational unit dedicated to safety: the Flight Safety Inspectorate. This followed a major accident in which a military plane crashed into a school and killed 12 people. The accident seriously compromised the image and reputation of the ITAF. The new risk management system was based on the principles of just culture and it was designed to encourage error reporting and learning from errors.

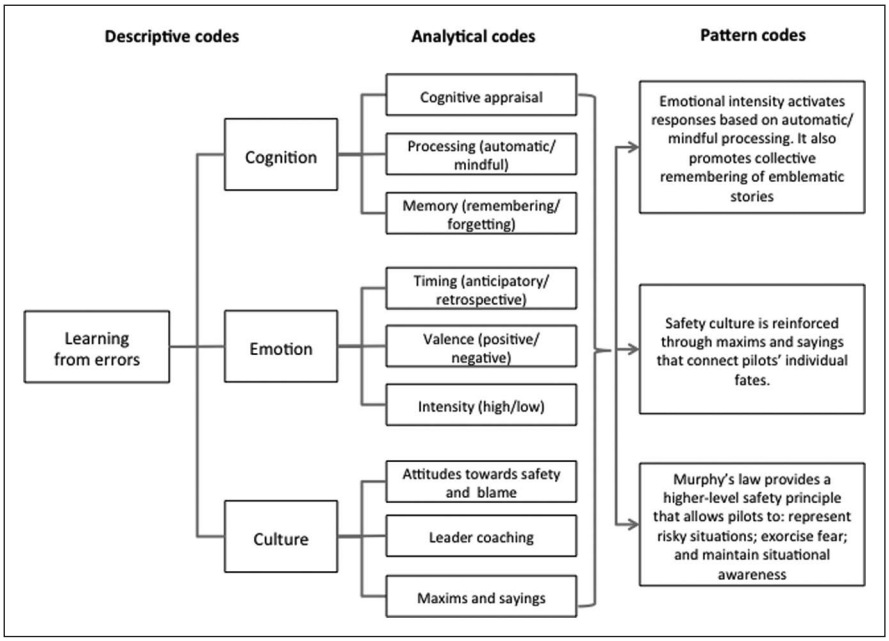

Figure 1. Coding architecture.

Before 1991 about 100 events were reported every year. After the constitution of the Inspectorate and thanks to the new safety policy based on the principles of just culture, the number of events reported has significantly increased. Figure 2 depicts the number and rate of incidents reported, distinguishing incidents due to human factors (grey columns) from the total (black columns). The vertical axis measures the rate of incidents per 10,000 hours of flight, while the actual number of incidents is reported above each column. The graph indicates that the reporting of incidents in the period considered has increased nearly fivefold, rising from 410 reports in 1991 to 1,922 reports in 2009. A similar trend is visible when focusing on incidents caused by human factors (e.g., lack of situational awareness, unsafe acts, lapses, slips, etc.), which are the most difficult to report because of the pilot's emotional involvement. In 1991 only 22 such incidents were reported, compared to 650 in 2009.

Figure 3 and Table 2 illustrate the impact of the new error reporting system on accident and death rates. According to the ITAF's definition, an accident occurs when the pilot dies, or when the pilot survives but the plane is destroyed. Figure 3 depicts the yearly trend in the number of flight accidents since 1991, demonstrating a visible decline over the years.Table 2 summarizes this trend over the last three decades. In the period 1980–89, the ITAF registered 87 accidents, which correspond to a rate of 0.59 accidents per 10,000 hours of flight. In the period 1990–99 this rate declined to 0.38 accidents per 10,000 hours of flight. In the following decade, 2000–10, the rate continued to decline, reaching the value of 0.32. Overall, Table 2 shows that the rate of accidents was reduced by 50 percent over the two decades. Although Figure 3 and Table 2 do not provide conclusive evidence as to the causes that have led to a decrease in accident and death rates, we can arguably infer a significant correlation between the new error reporting system and the improvement of safety conditions. It is important to point out, however, that improvements in flight safety partially result from other factors that are not directly linked to the incident reporting system, such as technological innovation and adoption of best practices available within the sector.

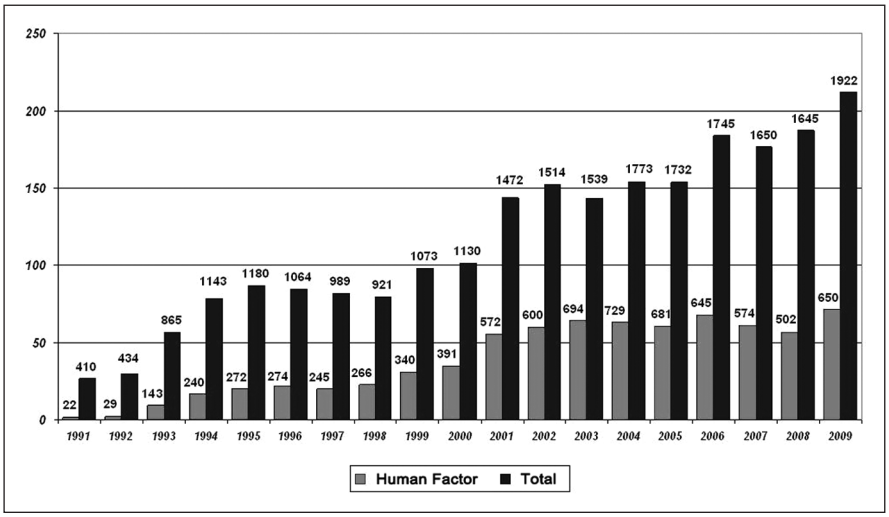

Figure 2. Flight incident reporting 1991–2009: average number of reports per 10,000 hours of flight. (*Source*: ITAF Flight Safety Inspectorate).

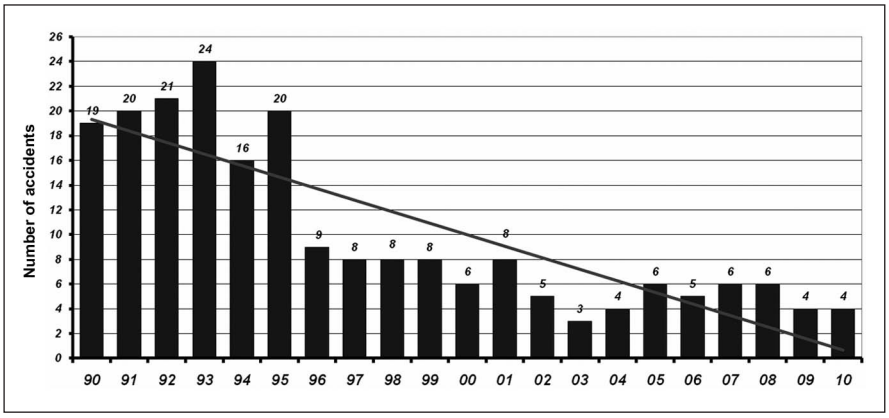

Figure 3. Flight accident rate 1990–2010.
(*Source*: ITAF Flight Safety Inspectorate).

Pilots in Action: Briefing, Flight Mission, and Debriefing

The analysis of what follows is based on the observation of pilots in situ as well as informal conversations with them. The purpose of the analysis is to provide a descriptive narrative of pilots' operational activity, which we articulate as a sequence comprising three main phases: briefing, flight mission, and debriefing. The narrative focuses on the pilots' "sayings" and "doings" (van Maanen, 1988) and it incorporates quotes extracted from the pilots' own accounts.

Briefing

The working day of mission-active pilots begins with the acquisition of information relating to their task: weather conditions, intelligence data, information concerning available airports for

Table 2. No. of accidents 1980–2010.

Period	Number	Rate	Deaths
1980–89	87	0.59	61
1990–99	51	0.38	43
2000–10	33	0.32	22

(*Source:* ITAF Flight Safety Inspectorate).

emergency landing, information about aircraft to be utilized, etc. This information is then shared out in the briefing held shortly before takeoff. In particular, the briefing serves to ascertain that before setting out the pilots: (a) know and share all the information; (b) share the general objective to achieve during the mission (for example, flying at a low altitude, reaching a particular target); (c) share individual objectives (who does what, what has to be learnt individually); (d) are aware of the aspects relating to flight safety.

The briefing lasts about 45 minutes and involves all the pilots who will take part in the mission. In cases where the mission is especially complex, other personnel may also participate. The briefing is divided into a general section (common to all briefings) and a section specific to the mission. The former, known as *motherhood* by some units, lasts about 15 minutes and provides a recap of all the routine procedures for the various phases of the flight: parking, taxiing, takeoff, weather conditions, refueling, return, landing, taxi back. This activates the attention and awareness of the group. The specific part of the briefing (in jargon, the *meat of the mission*) regards the tactical aspects of the mission, e.g., physical dangers or lack thereof, a description of the target, line of attack, and so on. This takes about 30 minutes. Just a few minutes before departure there is the *step-out* phase, lasting 5–7 minutes, where any last-minute additional information is supplied (if, for example, any conditions have changed in the meantime, such as the weather, aircraft, airfields, etc.) and the mission's risk matrix is created. Where required, variations and alternative plans are defined.

The pre-flight briefing represents the last tool for a leader to create the same initial situational awareness for all the members of the formation. As one pilot remarked:

> A good mission brief should cover what is expected of everyone at every point in the mission. This will greatly increase the chances of a pattern match and improve situation assessment. You should also discuss potential risks throughout the mission, and discuss plans to reduce those risks. With those risks assessed prior to flight, the available choices during flight will be easier to sort and lead to more predictable action.

Briefings are chiefly characterized by the cognitive dimension. They are oriented towards the acquisition of information regarding factors which might influence the mission. They are based on a process of evaluation of risk and the definition of rational courses of action. Emotional aspects are also present, with emotions of an anticipatory nature, both positive and negative. For example: (1) *The desire to make a favorable impression* towards colleagues and superiors (positive emotion), in particular for a pilot in training. What a pilot does will earn him the esteem of supervisors and peers. It may happen, however, that a pilot manifests attentive behavior while in reality not paying attention. (2) *The fear of making a mistake* (negative emotion), which may cause a pilot not to speak out because of the fear of saying something inappropriate or wrong and therefore, feeling unsure, remaining silent. The mission leader's role is extremely important in understanding the emotional state of the participants during the briefing: "looking them in the eyes" and recognizing if there is any tension or fear, listening, and observing body language. For example, a type of

behavior held to be negative is when a leader explains the mission at the blackboard, back turned to the team, not looking them in their eyes nor observing if they are tired, worried, or fully aware of the mission to be carried out. A briefing is characterized by certain basic values shared by the pilots and reinforced by training and ongoing communication, such as: complete attention to all the activities to be accomplished, the situational awareness of the briefing room, the mindfulness for each single aspect, both large and small, open communication, and participation. These values are critical to understanding important aspects of the mission and being a collaborative participant in the mission itself.

Flight mission

Following the briefing and after preliminary suiting up, the pilots transfer to the aircraft on the parking apron for start-up, tests and technical checks, and then take off. A mission normally consists of between two and six aircraft (individual or two-man depending on the type of plane). There are three types of mission: training, operational, and real. Training missions are dedicated to maintaining the pilot's currency with respect to various activities. Operational missions are also training exercises but involve other personnel, such as pilots from other bases, armed forces or countries. These are more complex due to the coordination required between the various elements involved. Finally "real" operations are those that arise from contingent requirements, such as war zone missions, the interception of an off-course aircraft, scrambles for particular events, etc. During flight, communication tends to be standard: little is said and, when it is, it should be clear and concise. The leader coordinates and gives orders. It may happen, however, that a member of the formation spots something that the leader has not seen. In this case, it is the former who gives the orders, taking command temporarily and thereafter explaining why (e.g., "threat at X o'clock…., do Y"). This is a matter of "coordinate leadership" (Westrum, 1997) in which the leadership role shifts to the person who currently has the answer to the problem at hand (Weick & Sutcliffe, 2007). The person who decides, in other words, is the one who has the greatest situational awareness.

Emotions, both positive and negative, play a relevant part, and both, if managed badly, may have a negative outcome. For instance, the desire to make a favorable impression may induce unnecessary and dangerous behavior in a pilot, such as trying to assume leadership when this is not required, or diminishing situational awareness. Negative examples might involve a pilot during the flight realizing that something is wrong but not communicating the fact because of his fear of making a mistake, of not seeing or understanding something correctly, thinking to himself: "Anyway, he's the leader." The same emotion, such as fear, can play a double role, both positive and negative. Negative, it can paralyze behavior, reducing the pilot's operational ability, and fostering a submissive attitude. But fear may also be positive because it allows the pilot to measure external reality, like a kind of thermometer. As one pilot put it: "Fear can be a positive emotion because it helps you realize that you have gone beyond your limits or that you are in the presence of a truly dangerous situation." The awareness of emotions and their control are a vital part of the pilot's flight activity.

Missions are stressful for the pilot both from the physical point of view (fatigue) and from the cognitive and emotional perspective. Ongoing attention is required regarding everything that is happening inside the cockpit (instruments) as well as outside and in the formation's communication network. The re-entry phase is paradoxically the most problematic. Since this is the simplest operational part of the mission, a reduction in cognitive (situational awareness) and emotional (relaxing, "the worst is over") activity can be induced in the pilot, which can lead to error. In order

to control potential lapses of attention, pilots are repeatedly advised that "the mission finishes when the motors are switched off," in other words, back on the parking apron of the base.

Debriefing

After the mission, which lasts about 1½ to 2 hours (or longer for complex missions with refueling in flight or for non-tactical missions such as transporting people or equipment), the pilots change clothes, have something to drink and, usually within half-an-hour of re-entry, begin the debriefing in a room suitably equipped with a variety of auxiliary didactic materials: maps, video players, and TV screens to show the film of the flight. Debriefing, in a military context, is used to analyze the missions, the objective being to increase the effective acquisition of experience through cognitive and behavioral learning. It is an instrument employed to identify any eventual errors made during the mission with the aim of improving pilot performance. During the debriefing, various matters regarding both the training and safety aspects of the flight are analyzed, thus creating a reference point for a continuous and constant improvement in daily flight activity. In particular, debriefing provides a comprehensive post-flight review (Ron et al., 2006), ensures that all participants share the same view of events, and highlights lessons learned. Several air force pilots remarked that debriefings are critical to the learning process: "The debrief is where you can change your perceptions about the options you had and pick better ones next time." "A quality debrief is as important as the flight for learning purposes." "In a nutshell, we debrief to improve our performance and to solve any problems which may have come up."

A debriefing session can last from 30 minutes to two hours. In general, all the crews directly involved in the mission take part, sometimes with the participation of other personnel. After an introductory phase in which certain fundamental aspects of the flight are dealt with (such as safety), the various stages of the flight are gone over in the same sequence as in reality. The debriefing, above all, focuses on any anomalies that occurred during the flight. For example: (1) during the flight, one of the aircraft found itself in a position different from the expected one. It is necessary to understand why and how the pilot was forced into this situation: was it a lapse (forgetting what had been agreed)? A necessity? (weather conditions induced the pilot to modify his position)? Or something else? (2) Refueling in flight took too long: why? Did weather conditions cause the hose to shake? Was the pilot not able to connect the hose successfully? Or something else? Learning takes place especially when unexpected events of various kinds and with various consequences occur, which lead to a process of finding solutions to the problems and placing checks on variance through cooperation and communication between the pilots.

The climate is a participatory one based on mutual trust and respect. While in pre-flight briefings, anticipatory emotions—such as performance anxiety vis-a-vis superiors and colleagues—tend to prevail, in the debriefing there is the fear of being judged for not having performed well. All the pilots contribute to the discussion and collaboration is expected from all the participants, but the role and style of the leader in conducting these meetings are crucial. The orientation is towards the analysis of the event and not a matter of "pointing the finger." During the discussion of unexpected errors or problems emotional aspects are also brought into play, with questions such as "What sensations were you conscious of? How did you feel at that moment?" Successive to unexpected events, some pilots have responded: "I didn't feel comfortable while …," "I felt overwhelmed," "There wasn't a lot of communication with the others…" Overall, a debriefing makes it possible to improve personal awareness and interpersonal trust through the integration of cognitive, emotional, and cultural principles that support post-action reflection and increase a pilot's fund of knowledge and experience.

Learning from Errors in the ITAF

Having provided a descriptive narrative of the pilots' core activities, in this section we draw on interview and documentary data to analyze pilot accounts of learning from errors. We organize our analysis according to the three key dimensions of cognition, emotions, and safety culture and we infer patterns regarding the interaction of these dimensions in shaping learning from error processes.

Cognition and learning

The cognitive dimension of learning from errors was pervasive in the pilots' accounts. Two aspects of cognition were particularly salient in our data. The first was the pilots' discussion of the interplay of routine and mindful processing during flight missions and how that affected their appraisal of risky situations. The second was the pilots' portrayal of errors as a result of a chain of events, which they symbolically represented through the image of "Murphy's law."

Pilots often stressed the importance of relying on routines, procedures, checklists, and protocols, and of carefully preparing the mission while on the ground. On the other hand, they often mentioned routine and habit as the most common causes of flight mishaps. Several pilots referred to routines as a source of mindless behavior, which could induce a decrease of situational awareness and potentially lead to a cognitive switch-off (what is normally referred as "automatic pilot" mode):

> Most errors are caused by routine, which makes one act mindlessly: "I have done something wrong for 10 years, but I have always got away with it, and I keep doing it like that." This is one of the most serious mistakes.

> …. That mental "safety" red light that sometimes pops up in our thoughts has been switched off, you can proceed in a relaxed manner…. Technically, the problem is already there and it's only waiting for the moment to manifest itself.

Two cognitive dynamics were particularly salient in explaining the dysfunctional effects of routines on learning: negative transfer and expectation bias. First of all, pilots perceived routines as a source of rigidity, which could prevent adaptive responses in the face of changed circumstances during the flying situation. One pilot made explicit reference to the cognitive notion of "negative transfer" to explain how routines could impair learning. Negative transfer occurs when a learned and previously adaptive response to one stimulus interferes with the acquisition of an adaptive response to a novel stimulus that is similar to the first (e.g., Postman & Stark, 1969). A common example is switching from a standard transmission vehicle to an automatic transmission vehicle. The following quotes explain how a simple change of plane or an amendment to the landing runway due to adverse weather conditions requires a degree of adaptation that challenges consolidated habit patterns and may affect pilot behavior:

> They're the so-called "negative transfer" events, those mental mechanisms like for example… if I always go from the Pratica di Mare airfield to Milan's Linate airport and I always land on runway 36 and one day there's a strong wind and they tell me to land on 18 instead and I'm not thinking properly about the fact that they've changed the runway, then that can cause an error, which in reality is an error of routine.

> The pilot is someone who acts by routine, there are acquired mechanisms, habit patterns, a cycle of constant operations which always remain the same… for a pilot, all you have to do is change plane and, changing the interface you're habitually used to working with, there exists a period of adaptation which

> can take up 3, 4 or 5 missions where performance is noticeably slowed down because of these changes in habit patterns. Routine helps and is indispensible but it can also become a danger.

Second, routines set expectations that prompted pilots to carry out their task as "business as usual." Expectations could act as an invisible hand that decreased attention and generated biased interpretations of the flying situation (Weick & Sutcliffe, 2007):

> I look at the light on the cockpit, I expect it to be green and I see it green even if it is red…

The occurrence of unforeseen events would defy sticky sequences of routinized behaviors, undermine a pilot's ability to control the situation, and ultimately cause errors:

> Routines mechanize and standardize. Things become automatic… routines make you execute operations in a mindless fashion, therefore if one day something unforeseen happens… it could be that the sequence of mechanical behaviors goes on, even though I should be more aware of what I am doing.

The causal chain culminating in errors can be summarized as follows: routines are associated with mindless processing, which potentially decreases a pilot's level of attention; routinized behavior is reinforced over time and it may consolidate sequential action chains that gradually become habitual and taken for granted; the occurrence of unforeseen circumstances challenges existing habits and routines; failure to recognize unfamiliar situations may lead pilots to respond through habitual behavior; the mismatch between unexpected events and adequacy of response ultimately leads to errors.

Pilots characterized the chain of events potentially leading to errors in terms of the infamous "Murphy's law." The latter provided a means of framing errors symbolically as well as normatively:

> Behind each mishap there is a chain of events that leads you to an error; that chain is Murphy's law.

One pilot referred to Murphy as the "K variable" and linked it to the pilot's bounded rationality. His reasoning underscored the cognitive complexity of the task and the impossibility of planning all possible scenarios. Murphy is the "unexpected," but ironically it manifests itself when things are seemingly fine and one is cognitively (and emotionally) unprepared to deal with a sudden change of circumstances:

> … flying is a complex system, there are so many different variables that it is impossible to calculate all of them. Above all, human beings are not designed to be in an environment which is not their own, such as the air, and to handle such a complicated system as an airplane… And when the K variable (meaning something unexpected) comes out… the K variable is Murphy, the one that is impossible to plan for… this K variable doesn't usually appear when you're relaxed, when the weather's fine and everything is running smoothly, rather it is a combination of things which all come together unexpectedly.

A case reported in *SV* provided an explanation of how Murphy, the incarnation of a fortuitous event, would expose the vulnerability of an aircraft's safety system and potentially lead to flight mishaps:

> The trigger is provided by a fortuitous event (Murphy's law), which combines the following elements at a time when the system is vulnerable: 1. Human errors; 2. Mechanical failures; 3. Weather conditions. Each of these elements is critical in itself, but it is the combination among them and with other causal factors that can disrupt, bypass, or remove the aircraft safety system. (*SV*, issue 257)

At the individual level, a primary competence of the pilot was, therefore, being able to understand and interrupt an unfolding chain of events in order to avoid possible negative outcomes. In this regard, Murphy's law was a critical sensemaking resource that emphasized alertness and situational awareness. It was a way of urging pilots to be mindful in the face of the risks associated with the task:

> Murphy's raises your awareness and degree of attention… it makes you not underestimate things.

> Murphy's law keeps you alert… Flying missions with this awareness helps you see possible risks without taking anything for granted.

Overall, the pilots' accounts of flight missions connected the occurrence of errors and near misses to the cognitive rigidities associated with routine behavior, which could potentially lead to failure in detecting unforeseen circumstances. At the same time, they pointed out the role of situational awareness—evoked through Murphy's law—as the correct way of dealing with risky situations and managing the unexpected.

Emotions and learning

Our analysis of the data uncovered two main emotion-related patterns underlying learning from error experiences. First, emotions activated response patterns based on automatic/mindful processing, which influenced the pilots' handling of errors and risky situations. Second, emotional intensity affected collective remembering and the internalization of emblematic cases of flight mishaps.

The task of preparing and flying military missions is associated with risk and the management of the unexpected, which generate arousal and anticipatory emotions such as anxiety, fear, and panic. The flying space cannot be taken for granted and the pilots need to stay alert throughout the flying mission. Pilots often portrayed flying situations as characterized by a tension between emotion and cognition, instinct and rationality, excitement and control. For example, one of the cases reported in *SV* was significantly titled: *"Fear: from fright to reasoning"* (*SV*, issue 236). In many cases the pilots' accounts of errors emphasized negative emotions. For example, several pilots linked negative emotions to fear of being judged by colleagues:

> Errors can have emotional causes: For example… if I fly with someone I don't feel comfortable with or I believe may be judging me, then I may be negatively influenced and commit mistakes…

> Negative emotions are those connected to something that we have done badly… the fear of being judged by others, the fear of not being found up to scratch, the fear of not knowing the conditions and the times in which we have to show that we are good enough.

The connection between emotion and potential errors was mediated by cognitive processing. For example, negative anticipatory emotions seemed to decrease pilots' level of attention and lead to less effective handling of risky situations. This was because negative emotions diverted attention from the task to the handling of emotional pressure. The example below illustrates how flying with relaxed vs. stressed colleagues could result in emotional contagion and generate different forms of cognitive response:

> When on the other hand I happened to be flying with more easy-going people, people who didn't stress me out, I was able to realize a bit beforehand if I was going to make a mistake or not. I was more relaxed.

> While if I had someone next to me who was shouting, maybe repeating the same thing over and over, that was something that might be useful the first time, but if it went on and on then my attention would stray, I'd get distracted… my mind would get overwhelmed by this person shouting in my ear.

Interestingly, however, it also emerged that positive emotions could lead to automatic processing and, as illustrated earlier, link to mindless behavior. For example, the natural inclination to "make a good impression" or "showing off" could decrease the pilot's level of alertness during the preparation and execution of a flight mission. The following quote illustrates how overconfidence could generate pathological forms of information processing. Note how potentially dangerous behavior is singled out and addressed through Murphy's law:

> There's another air force saying that's very similar to "Murphy's law" and that's "What happened to Safe and Sound." If you ask someone, "Have you done that?" and the other responds, "Relax, everything's safe and sound," the answer is "Safe went down in flames and Sound went with him." And that's the sense of Murphy's law, that when you think you've got everything under control—then, watch out!—because there's always the possibility that something's going to happen that you haven't bargained for. It's like a wake-up call to be in a state of alert mindfulness and not get too relaxed.

The impact of emotions (either negative or positive) on cognitive responses seemed to depend on emotional intensity. High intensity emotions led to extreme forms of cognitive processing (cognitive paralysis in the case of negative emotions vs. cognitive switch-off in the case of positive emotions). Under these circumstances, preventing errors was contingent upon the pilot's ability to either rationalize and dominate high intensity emotions (e.g., from fright to reasoning) or maintain a discriminatory capacity for noticing in apparently routine circumstances (e.g., by rehearsing Murphy's law). The above evidence suggests that emotions influence forms of information processing and thereby affect a pilot's response to the situation. This is an interesting finding because it seems to imply a double causal link between cognition and emotion: the initial appraisal of the situation generates positive/negative emotions which activate patterns of response based on automatic/mindful processing. In turn, the effectiveness of the response depends on the pilot's control of emotional intensity.

Reported stories of errors often evoked issues of risk, danger, life and death. These stories were, therefore, emotionally salient. Emotional experience made certain occurrences emblematic and noteworthy. Our analysis of the cases reported in the *SV* magazine was particularly illuminating in this respect. The magazine reports emblematic stories of mishaps or near misses in the form of case studies and it is widely read in the ITAF. Each case study contains a description of the main event, an analysis of the accident or mishap, and a commentary on "lessons learned" (a moral of the story). Table 3 displays an emblematic story involving two helicopters. The story starts with an emotionally oriented premise, a public confession aimed to dramatize the episode and turn an individual experience of learning from errors into a collective one:

> It's been a while since that distant November 2001, but every time I fly a mission, I cannot avoid remembering a near miss that happened to me and never confessed before, as well as the related "lesson learned" from it. Now I feel it is time to share that event, in the hope that it could teach something to all those who spend their life up in the air. (*SV*, issue 260)

The storyline illustrates how the combination of adverse weather conditions (a sudden storm impairs visibility of the flying space), a faulty instrument on board (the altimeter is displaying inaccurate measurements), and the "person-to-person interface" (miscommunication between co-pilots) could have escalated into dramatic consequences. The co-pilot (the author of the case) is the "positive" figure of the story, who is able to make good sense of the situation, gain control of his

Table 3. An emblematic story of a near miss (*SV*, 260/2).

Weather conditions were rapidly deteriorating … Speed was decreasing, turbulence was causing variations in trim with bank angles of around 40 degrees and variations in speed of 30 knots.
…I noticed that our helicopter was rising with respect to the other 'copter [the leader helicopter], which started to disappear under our nose. I communicated to the crew chief, at that moment at the controls, that I'd lost visual contact with the leader and, not getting any feedback from the other crew members, I passed from visual scan internally to instruments, reporting the flight data continuously and continuing to note an effective, considerable increase in altitude which would have taken the 'copter into the storm.
I continued to rap out the flight parameters to the pilot at the controls, who did not however take any action to reduce the rate of climb and increase speed—in fact, he stated that he had indications of reduced altitude and that he was trying to maintain a low speed to carry out a water landing. At that point… I realized that his instrument scan was jammed on the radar altimeter which was not giving reliable readings, indicating a constant decrease in altitude, and as a consequence he was ignoring the readings of the barometric altimeter and the vertical speedometer which were constantly increasing.
Reaching an altitude of 3,000 feet with speed almost zero, a 30-degree pull-up and a 20-degree bank to the left, I noticed an inverse tendency in the climbing speed and we began to descend rapidly with a strange trim.
From the porthole I saw that the heavy rain which had been pouring down before was now windmilling from low to high, indicating to me that we were in fact going down. I heard the crew and passengers shout, there was a strong buffet of turbulence which knocked off the lower cover of the transmission and a considerable amount of water came into the 'copter, so much so that it reached my station and soaked me.
We were still at a certain level of altitude but the pilot at the controls reported to me that he was convinced we were close to crashing into the sea. Fortunately this was not the case. After initial resistance he began to have doubts about his own perception and believe my readings. At this point, despite his fear that a variation in trim would mean a high-speed water landing, he decided to turn the control of the helicopter over to me.
Trusting in the readings from the barometric instruments and ignoring the radar altimeter which was by now showing zero, I managed to gain speed, level out the 'copter and force it into a controlled descent. At a barometric altitude of about 300 feet, we finally regained sight flying conditions with the coastal lights clearly visible.
Fortunately on this occasion the chain of events was broken; the flight crew of expert pilots should however have given greater value to all the information available and not fallen into the "trap" of overconfidence. Only one link in the chain was lacking to bring about an accident. The man-to-man interface, that is the interface between the people, in this case the crew, was the main negative element here. Luckily, however, an adequate level of CRM, even though a little belatedly, managed to induce some excellent team work that helped them out of a very dangerous situation and allowed them to be able to recount this particular event.

emotions, take command of the airplane, and successfully break a dangerous chain of events before it is too late. The moral of the story revolves around effective crew resource management (CRM) under critical circumstances.

Emblematic stories also illustrated the connection between negative emotions and safety culture. This was apparent in stories of error reporting. For example, negative post-hoc emotions involved in public confessions reinforced the diffusion of safety principles from the individual to the organizational level. One pilot linked lack of reporting with feelings of shame and regret:

> I am sorry I felt ashamed and I did not report a bad event. I am convinced that many of us have not reported some events. It is not difficult to write down two lines to inform others. You would never know how many errors you can avoid by telling the truth. But if we do not do it and then something bad happens it is very difficult to live with this regret. (*SV*, issue 245)

Finally, emblematic stories of flight mishaps made recurrent reference to Murphy's law. Here Murphy was often used, in the words of one pilot, "as a gloss on the narration of the story." It was a dramatizing device that endowed the narration with a certain chill and thereby made reported stories more memorable. Here are a few examples extracted from the ITAF magazine *SV*:

> I can affirm without the shadow of a doubt that I personally witnessed that… Murphy exists!! (*SV*, issue 236)
>
> …those endless ten seconds in which anything could happen while Murphy was there enjoying the scene! (*SV*, issue 237)
>
> Murphy exists and is always waiting for new subjects to remind them of his subtle presence. (*SV*, issue 250)

Emblematic stories reported by the pilots turned individual experiences of errors and flight mishaps into cases, characterized by a specific plot, high emotional content, and a lesson to be learned. In so doing, they defined a distinctive process of "learning by examples" (Patriotta, 2003b). Reference to Murphy's law allowed pilots to not only make retrospective sense of the chain of events leading to flight mishaps (cognition), but also convey the emotional intensity of flight experiences (emotion). The emotional aspect of emblematic stories supported the pilots' internalization of lessons learned and promoted processes of collective remembering (Middleton & Edwards, 1990; Walsh & Ungson, 1991; Weick, 1988). This can be explained in terms of cognitive appraisal: an emblematic story was such because it was directly relevant to a pilot's well-being. This generated an emotional response and promoted the internalization of the story as an archetypical situation of danger culminating in a successful resolution. Furthermore, emblematic stories seemed to play an important role in the development, maintenance, and reinforcement of a shared safety culture. It is to this latter aspect that we turn in the next section.

Safety culture and learning

The analysis of safety culture adds an additional layer of complexity to the dynamics discussed so far. It connects individual cognitions and emotions to contextual factors. This allows us to appreciate how the cognitive and emotional dimensions of learning from error operate at the group and organizational levels. Our analysis of the data uncovered two main culture-related dynamics underlying learning from error experiences. First, safety culture affected the definition of pilot identity and had a mitigating effect with respect to those impression management attitudes that could lead to unsafe acts. Second, safety culture affected how pilots channeled negative emotions and converted negative experiences into learning opportunities.

Pilot identity was grounded in the broader cultural system of the ITAF in which safety was seen as a public good, and reporting errors constituted a sort of ethical principle. In this regard, safety culture downplayed individualism and encouraged the sharing of information and knowledge about errors. This marked an important discontinuity with the past, when the ITAF had been characterized by a pervasive "macho," individualistic culture. A pilot was typically portrayed as a fearless individual who despised risk and danger and could heroically cope with any kind of situation. Within such a mythical portrayal, errors could compromise the professional image of the pilot and lead to loss of face, feelings of shame, loss of self-esteem, and peer pressure. In contrast to this view, a senior pilot remarked that "the expert pilot is one who has seen and been through many errors." Another pilot further articulated the contrast between old and new safety culture:

> In the past pilots used to say "I am a pilot, I am cool." 20 years ago there was a tendency to break the rules, for example, flying the aircraft under a bridge. Today, nobody does that anymore. Fortunately, today there is a general awareness of discipline and flight safety, to the point that the more a squadron reports flight mishaps the higher it is regarded. Therefore you are motivated to report.

Safety culture linked individual responsibilities to the protection of colleagues and highlighted the importance of diffusing safety principles at the organizational level:

> Among the responsibilities of a pilot there is the protection of colleagues from the intrinsic dangers of this job. Thus, we need to diffuse knowledge and information as a key tool to improve defenses against errors and we need to teach that the more you advance in your career the more you have the responsibility to work towards fixing the latent failures and to diffuse a just culture about flight safety, without the fear of having committed an error.

> The more people I inform about my error, the less they risk repeating the error.

The diffusion mechanisms seemed to be based on a norm of reciprocity, which functioned as a sounding board ("military radio") for sharing knowledge, increasing situational awareness, and avoiding future errors:

> It has happened to me, it could well happen to you one day: this is the way we deal with errors.

> We are military forces, we have been taught that information that concerns one of us concerns everyone… some call it the military radio.

In addition to emblematic stories, safety culture was conveyed through sayings and maxims. Table 4 illustrates a few common sayings shared by the pilots. Like emblematic stories, these sayings had a normative value. They supported the pilots' retrospective sensemaking by reminding them of fundamental safety principles and helping them maintain situational awareness during flight missions. They reinforced the belief that pilots shared the same fate and encouraged the sharing of information. These sayings have been developed by pilots in the course of their work activity and they have consolidated over time. They usually arise as a result of reflections on noteworthy events linked to risk and errors. They are taught to newcomers in flight schools and they are evoked in the different flight departments. They emphasize, at times in a playful manner, certain areas of risk connected to flight operations. Taken together, they constitute a sort of "popular culture" which is mainly communicated and shared orally. Some of these sayings are conveyed through the cases reported in *SV* for which they provide the "moral of the story." They are also included in other formal documents such as audiovisual presentations, documents on safety, and training courses.

Although errors were typically associated with negative emotions, the principles of just culture provided a supportive context for error reporting. In particular, leader coaching was seen as a key mechanism for turning negative emotions into learning opportunities:

> A lot depends [regarding how people cope with emotions] on how the subject is handled by an instructor or superior. When a person is dealing with a management or supervision which doesn't have a problem with facing up to things and has no problem admitting errors… Because in the end, error is an instrument: an instrument that, however much experience you have, helps you to keep learning.

> In the past, when you came up against a more authoritarian type of leadership, things would never really come out, because of fear of… not so much of being punished, because in the past reporting a dangerous

Table 4. Maxims and sayings at ITAF.

1	In aeronautics there are two categories of pilot, those that have made a landing without the undercarriage down and those that still have to do it.
2	Hope for the best, prepare for the worst.
3	Those are the planes, you fly them today, I'll fly them tomorrow.
4	There are no new causes of incidents, there are only new incidents!
5	What happened to Safe and Sound: If you ask someone, 'Have you done that?' and the other responds, 'Relax, everything's safe and sound', the answer is 'Safe went down in flames and Sound went with him.'
6	You want to bet that's exactly what will happen.
7	There are old pilots and there are bold pilots, but there are no old, bold pilots.
8	Learn from the mistakes of others. You won't live long enough to make them all yourself.
9	Mistakes are always the same, it's just the people who make them that change.
10	Look out for the cloud with a stone in it.
11	Things that are no use to anyone: the runway behind you—the altitude above you—the fuel you didn't put in the tank.
12	There are pilots who concentrate so hard on dying that sooner or later they get a degree in it. [Said regarding undisciplined pilots]
13	The mission is finished when the motors are switched off. [i.e., on the parking apron back at base]

> event didn't necessarily give rise to punishment… but of being laughed at, of losing credibility with regard to the job you do. That happened in the past. I don't see this type of situation nowadays, it's the sort of thing that hasn't happened for a number of years now.

The above quotes reiterate the importance of leadership style, which we previously remarked when reporting on the observation of briefing/debriefing sessions. They suggest that emotionally intelligent leaders, through understanding and regulation of their own and others' emotions, are able to form empathetic and constructive relationships with their followers. This is consistent with Zhao's (2011) finding that negative emotions can stimulate motivation to learning from errors when leaders encourage a positive and constructive view of errors and thereby alleviate individual tension and stress.

Discussion and Conclusion

The primary purpose of this study was to investigate the dynamics whereby cognitive, emotional, and cultural factors work together in driving processes of learning from errors. Specifically, we asked: How does the interaction of cognition, emotions, and safety culture influence the detection, reporting, and analysis of errors in organizational settings? Based on the findings of our study, the framework in Figure 4 summarizes how selected aspects of cognition, emotion, and safety culture inform processes of individual and organizational learning from errors. Below we draw on the framework to outline the main theoretical contributions that can be derived from our study.

Cognitive appraisal, emotions, and information processing

Our study suggests important connections between individual cognitions and emotions. Situational awareness and mindful processing of available information are essential in accomplishing risky tasks, such as flying military missions. Cognition becomes particularly salient when individuals face unexpected circumstances and thereby need to switch from routine processing to conscious

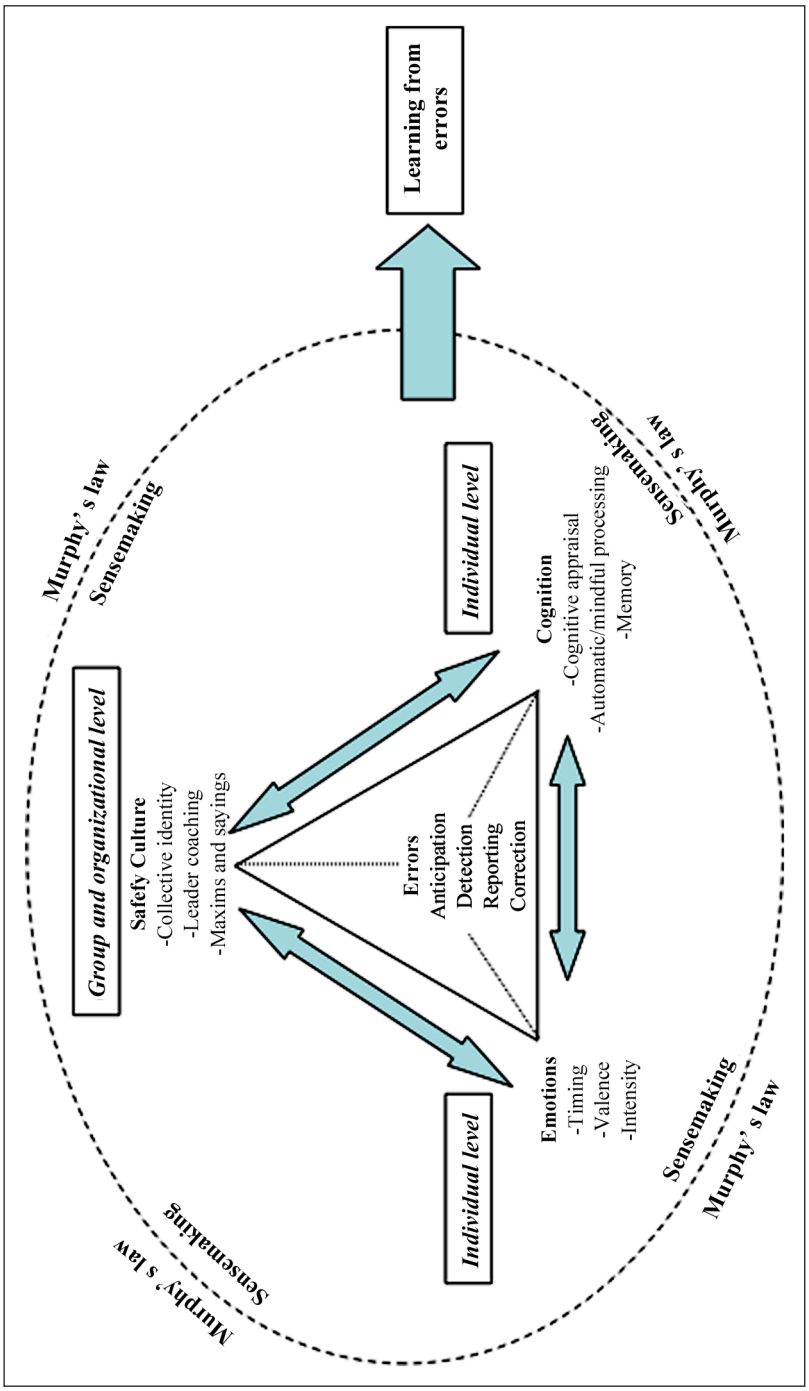

Figure 4. A model of organizational learning from errors.

awareness (Louis & Sutton, 1991). One main finding of our study is that cognitive appraisal of the situation (e.g., deviations from the expected) affects emotional states (timing, valence, and intensity), which, in turn, activates forms of information processing (automatic/mindful). In the case reported, anticipatory emotions prompted pilots to maintain an awareness of their experience during the preparation, flying, and debriefing of missions. This awareness was critical in noticing how particular situations evolved and in drawing lessons from particular chains of events. Furthermore, post-hoc emotions related to the (public) reporting of mishaps and near misses promoted reflective processes and favored the internalization of noteworthy experiences as "lessons learned." This reinforced the values of just culture and contributed to reproducing those values throughout the organization.

Previous studies have mainly focused on the influence of negative emotions on learning from errors, often with contradictory results. Several scholars have suggested that negative emotions impair learning by decreasing motivation to learn (e.g., Ilgen & Davis, 2000; Kanfer & Ackerman, 1989). In particular, it has been argued that negative emotions divert cognitive attention from on-task activities (such as learning) to off-task activities (emotion-focused coping). More recently, Zhao (2011) unexpectedly found that a significant and positive association might exist between negative emotionality and motivation to learn and explained this finding by arguing that negative emotionality dampens motivation to learn only when it is of moderate or strong intensity. Our study considers the influence of both negative and positive emotions on cognitive processing. In general, negative emotions are more noticeable and tend to be associated with mindful processing, whereas positive emotions are commonly associated with automatic processing. However, our findings suggest that emotional intensity plays an important role in promoting routine/mindful behavior and related learning from errors. While extreme emotional states tend to activate excessive forms of cognitive processing that divert attention from the task (e.g., cognitive paralysis and cognitive switch-off), low to moderate emotional states are more likely to generate situational awareness. Furthermore, emotional intensity also affects processes of collective remembering. For example, the emotional twists experienced by pilots during flight missions (from negative to positive, from threat and fear to happy ending) promoted the internalization of noteworthy flight occurrences as learning cases. In turn, learning cases were institutionalized in the form of emblematic stories and publicized through the *SV* magazine. The temporal aspect of emotional intensity is important here: while real-time high-intensity negative emotions can lead to pathological forms of information processing, the passing of time offsets the extreme impact of emotions and facilitates the internalization of learning experiences.

From individual to organizational learning from errors

This study sheds light on the learning dynamics that connect individual cognitions and emotions to broader contextual factors. This contributes to the understanding of how individual learning from errors is linked to organizational learning from errors. Several studies have underscored the influence of contextual factors on learning from errors. For example, Edmondson (1999) demonstrated that team members' perceptions of psychological safety positively influenced error reporting and motivation to learn. More recently, Patriotta and Spedale (2009, 2011) have suggested that leadership is a fundamental sensegiving mechanism that influences group dynamics by conveying a common set of expectations about behaviors. Our findings confirm that context support—based on sharing the principles of just culture—encourages a positive attitude towards errors. It further suggests that leader coaching influences the (cognitive) channeling of negative emotions and increases motivation to learn. More importantly, our study illustrates additional contextual mechanisms

through which safety culture encourages learning from errors. In particular, we find that safety culture mitigates personal traits and natural inclinations such as pride, overconfidence, and willingness to impress by showing off. Such inclinations can decrease attention to the task and undermine individual and collective safety. This is because safety culture shifts the focus of attention from the performance of the individual pilot to the collective fate of the community of pilots. Our study suggests that safety culture principles—enacted as sayings, maxims, and conventional wisdom—promote the dissemination of knowledge about errors and provide a sounding board for collective learning from errors. Finally, our investigation of individual and organizational learning mechanisms resonates with the idea that organizational learning from errors is a multi-faceted process involving several dimensions (Lipshitz, Friedman, & Popper, 2006). Our research further develops the psychological and cultural facets of Lipshitz et al.'s framework and extends such framework by considering the role of emotions as an additional dimension.

Learning from errors as a sensemaking endeavor

While learning and sensemaking are often considered as kin concepts, a rather limited number of studies have addressed the interaction between learning and sensemaking and its effects on organizational performance. For example, Thomas, Sussman, and Henderson's investigation of a US Army training unit pointed out the role of sensemaking as a source of strategic learning, i.e., learning that leads to the generation of knowledge and superior performance (Thomas, Sussman, & Henderson, 2001). Weick and Sutcliffe (2003) have studied the interplay of learning and culture-driven sensemaking informing medical work at the Bristol Royal Infirmary. Their findings stressed the cultural blind spots that encouraged surgeons to produce convenient justifications for their poor results and prevented them from learning from errors, thus leading to repeated cycles of poor performance. Finally, as documented in the first part of the paper, HRO studies have linked learning to mindful organizing, a particular form of organizational sensemaking aimed at detecting signals of danger and preventing errors.

Our study sheds further light on the sensemaking–learning link. Conceptually, sensemaking denotes processes of interpretation and meaning production through which individuals and groups engage their worlds on an ongoing basis (Patriotta & Brown, 2011; Weick, Sutcliffe, & Obstfeld, 2005). Sensemaking arises when people encounter situations that defy their current understandings and call for correction or repair. Learning refers to the acquisition of knowledge that enables an individual or group to repair a problematic situation. Errors, whether actual or anticipated, provide an empirical intersection between sensemaking and learning. In fact, learning—the detection, reporting, and correction of errors—is contingent upon the way in which individuals or groups interpret a problematic situation to themselves. In this respect, errors play an essential role in processes of construction of reality. This construction revolves around cognitive, emotional, and cultural sensemaking, which may or may not lead to processes of learning from errors. A prominent sensemaking resource informing pilot learning from errors was Murphy's law.

Interestingly, this law ("If anything can go wrong, it will") originated at an Air Force base (Spark, 2006). It was named after Capt. Edward A. Murphy, an engineer working on an Air Force experiment designed to see how much deceleration a person can stand in a crash. The phrase was coined in adverse reaction to something Murphy said when his devices failed to perform. At a press conference held shortly after, the Air Force flight surgeon, Dr. Stapp, said that their good safety record on the experiment was due to a firm belief in Murphy's law and in the necessity to try and circumvent it. Thus Murphy's alleged usage and Stapp's usage of the

phrase are very different in outlook and attitude. One presents a quasi-fatalistic view of reality, which captures the common tendency to emphasize the negative things that occur in everyday life; the other is a positive statement on learning, indicating a belief that if one can recognize the possible causes of errors, steps can be taken so that they can be avoided. This latter connotation seems to apply to the ITAF case. The law—evoked and repeated as a "mantra" by the pilots—provided a sort of meta-level framework within which to understand potential errors and flight mishap. The law depicted errors as the result of a chain of events; it emphasized the importance of mindful behavior and close attention to small events, which could lead to major consequences. Pilots also evoked Murphy when retrospectively making sense of their flight missions. The imagined presence of Murphy was a way of coping with fears and the anticipatory emotions related to a risky task. Finally, the law was a collective representation of the pilots' beliefs, sentiments, and values regarding errors and risk. It provided a cultural norm that linked the fate of different pilots and thereby transposed individual experiences of errors to the organizational level. The context in which Murphy's law originated suggests that making sense of and learning from errors are rooted in institutionalized myths characterizing a specific organizational field (Meyer & Rowan, 1977). Such myths carry normative value and give sense to everyday practices within a particular work setting.

Limitations and directions for further research

Our contribution has been based on the analysis of a particular type of organization characterized by a risky task, extreme environmental conditions, and high relevance of issues related to error reporting and blame attribution. That our research has centered on a population of Italian military pilots with a number of unique features means that the particular linkages between cognition, emotion, and culture outlined here are specific to the empirical setting in which the study was conducted. However, while we cannot generalize empirically from these unique patterns of behavior, we suggest that the interaction between cognition, emotions, and culture underlying processes of learning from errors applies to other organizational situations, especially in relation to instances of breakdowns, crisis, and other forms of organizational failure. Understanding this interaction is essential for managing risk and promoting safety in organizations (Gephart et al., 2009). Future research might consider further questions that extend and validate the approach presented here. For example, how does the core organizational task affect the ways in which individuals and groups cope with and learn from errors? How does learning from errors in routine situations differ from non-routine ones? How do positive versus negative emotions affect cognition and learning from errors? What kind of emotions does the specific safety culture of an organization help to promote? How do sector recipes and institutional myths affect processes of learning from errors?

In conclusion, this paper has contributed insights regarding the interaction of cognition, emotions, and safety culture in processes of detection, reporting, and correction of errors. We have synthesized these insights into a framework that illustrates how cognitive, emotional, and cultural sensemaking inform the construction of errors and affect learning outcomes. The findings reported in this paper shed some light on the phenomenology of errors in organizational settings and provide a platform for understanding how organizations can manage errors and learn more effectively.

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