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Using a procedure doesn't mean following it: A cognitive systems approach to how a cockpit manages emergencies

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ABSTRACT

The resources for action idea suggests that procedures, although they appear to be constraints that control, direct and restrict actions, are in fact resources that support a wide range of actions. Whereas the notion has gained considerable traction in the academic discourse, few empirical studies investigated how procedures are used as resources or if they are the only resources deployed. This paper applies resources for action approach to describe how a cockpit manages emergencies and other non-normal situations and the role played by the Quick Reference Handbook (QRH). Data was collected through participant observation, interviews, and analysis of technical documents. The results indicate that some situations encountered by pilots are far more complicated than the procedure anticipates. In order to cope with these situations, pilots employed strategies that interleaved a range of resources, often consulting fragments of the QRH checklists rather than following them from start to finish. These findings suggest that emergency checklists should be divided into smaller units that can be followed independently, and that procedures should sometimes provide pilots with choices rather than mandatory instructions. The other resources deployed can also enhance the performance of pilots.

1. Introduction

In aviation, standardization of operating procedures has been used for decades as a key strategy for managing operations (Degani and Wiener, 1993). The epitome of standardized operating procedures is the Quick Reference Handbook (QRH), a set of checklists[1], performance tables and information about aircraft limitations (Burian, 2006a,b; Loukopoulos and Barshi, 2003). The checklists have typically been made of laminated cards, though electronic checklists are becoming more common. For the purposes of our analysis, we focus on the laminated cards format. Each card represents a particular situation or a warning system message, and contains an ordered list or a flow diagram of instructions to be followed (De Brito, 2002). These instructions aim to contain the failure, to restore the system or to conduct safely the flight with the inoperative system or component (Heymann et al., 2007).

Improvement of procedures has been an object of considerable interest in the literature, which points out the need to: (i) combine top-down and bottom up approaches to procedures management systems (Blakstad et al., 2010; Hale and Borys, 2013b); (ii) balance the restrictiveness of procedures (Grote, 2014; Weichbrodt, 2015) in order to avoid over (Bieder and Bourrier, 2013) and under specifications (Van der Lely, 2009); (iii) educate operators to better understand the reasons behind procedures content (Weichbrodt, 2015) and to deviate from procedures when needed (Saurin and González, 2013); (iv) engage operators in the conception and revision processes (Hale and Borys, 2013a; Weichbrodt, 2015); and (v) improve operators-procedures interface by physical and typographic changes (Burian, 2006b; De Brito, 2002; Degani and Wiener, 1993; UK CAA, 2006).

These initiatives reflect an understanding of procedures as organizational control. According to this approach, which we refer to as control instrument approach, procedures are important for safety because they constrain actions, coordinate the activities and present a record of knowledge about how to perform work

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[1] In this paper, the terms QRH, checklist and procedure are used interchangeably as synonyms of formal, written procedures, rules or safety rules.

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(Weichbrodt, 2015). This view is build on the idea that it is possible to cover almost all situations with procedures, that any gap between procedures and practice can be closed, compliance can all but be guaranteed, and, when it is not possible, means for dealing with exceptions can be proposed. This approach is useful for analysing the causes and consequences of non-compliance, and improving procedures accordingly. However, the *control instrument approach* makes assumptions that pre-suppose the very questions we wish to address. If pilots do not use checklists as control instruments, then findings about compliance and non-compliance are not relevant to understand the role the checklists play.

An alternative approach, referred to as procedures as *resources for action*, regards procedures as one among several sources of information to support operators to conduct a reasonable course of action given the particularities of the context (Dekker, 2003; Hutchins, 1995a; McCarthy et al., 1997; Suchman, 1987; Wright and McCarthy, 2003). From this view, instead of focusing on strictly following procedures, organizations must focus on how procedures can support the activity of managing anomalies (Woods, 1994; Woods and Hollnagel, 2006). Therefore, the design of procedures should support the strategies (Rasmussen, 2000) and must take other resources into account (Wright and McCarthy, 2003).

This approach challenges the status of procedures as a sufficient and complete prescription for practice. As pointed out by Suchman (1987), a procedure cannot fully specify the task, since it is based on an abstract representation of the work. Furthermore, the knowledge required to do the work is far more than the knowledge laid down in procedures; it is related to a deep understanding of systems, environments and particularities of the situation (Hutchins, 1995b; Wright et al., 1998). Instead of only trying to reduce the gap between procedures and practice, as occurs in the procedures as *control instrument approach*, organizations must also understand why the gap exists (Dekker, 2003, 2005), in order to redesign the work system. Despite the debate surrounding the use and value of procedures, there is a shortage of empirical evidence showing how procedures are actually used by real operators in real settings (Knudsen 2009; Wright and McCarthy, 2003).

The research question addressed by this paper is stated as follows: how does a cockpit manage abnormal and emergency situations? In order to answer this question, the paper applies a *resource for action* lens and reports findings from a study conducted in a major commercial airline. The paper aims to examine how a cockpit manages non-normal situations and the role played by procedures in this activity. The results provide some insights into the design of procedures and the cockpit.

2. Theoretical approach for analysing the activity

2.1. Procedures as resources for action

The idea of procedures as a *resource for action* comes originally from Suchman (1987). Suchman proposed the idea as a direct contrast to the prevailing view of procedures as control mechanisms that strictly guide action. From her perspective, plans, maps, scripts, protocols, procedures and rules do not determine actions. Rather, they are one among many different resources that support the operators to deal with or avoid local constraints.

Wright et al. (1996) elaborate the idea of *resources* to specifically include procedures, interface perceived affordances (i.e. degrees of freedom are reduced due to object's properties), and previous interaction history, since information is distributed across these resources. In line with these findings, Wright et al. (1998) and Wright and McCarthy (2003) point out that for any given non-normal situation in aviation, multiple checklists may be used in fragmented and interleaved ways. This occurs because inflight problems are not always solved in the same sequence stated by the checklists.

Wright et al. (2000) suggest the analysis of a *resource for action* should seek to reveal abstract information structures, i.e. the meaning given by operators to the piece of information extracted from the resource and the utility of this piece to solve a specific circumstance. Through this approach, the *resource for action* is a composition of meaningful information pieces. However, the study's conclusions are drawn from the analysis of software and might need adjustments in order to be used in complex activities analysis.

2.2. Cognitive system engineering: anomaly management

Like procedures as a *resource for action* provides the theoretical lens for this study, Cognitive Systems Engineering (CSE) provides a framework for analysing how operators and artefacts jointly manages non-normal situations (Hollnagel and Woods, 1999). The approach aligns well with the procedures as a *resource for action* lens, because it takes a holistic approach, stressing interactions between agents and technical artefacts rather than overemphasizing the role of individual system elements, such as pilots or procedures. Furthermore, CSE focuses on the functionality of the system instead of its structure (Hollnagel and Woods, 2005), which also draws the attention to how procedures interact (i.e. how they function) in a broader context.

The unit of analysis for CSE is the joint cognitive system (JCS), which is defined as a co-agency between people and technology that uses the knowledge about itself and the environment to plan and modify its actions in order to achieve a goal (Hollnagel and Woods, 1999). A JCS not only uses what is inside pilots' minds, but also representations distributed along the social and material structures (Hollan et al., 2000[2]).

Applied to non-normal situations management, the CSE perspective focuses on the dynamic and interdependency among the context, strategies and social and material structures (Hollan et al., 2000; Rasmussen, 2000). Strategies, in this sense, are composed by anomaly recognition, diagnostic and course of actions, and vary during the situation (Rasmussen et al., 1990; Woods and Hollnagel, 2006). As the JCS is embedded in the situational context (Rasmussen, 1993), its actions and reasoning unfold as an integrated and continuous flow, where no discrete actions and decisions are taken separately (Rasmussen and Jensen, 1974). CSE recognizes that the anomaly perception, diagnosis and the course of action are not separated and independent tasks; they are carried out in parallel, influence each other and must be interleaved with other activities to maintain the process continuity (Woods, 1994).

3. Research method

3.1. Scope of the study and sources of data

The study was conducted in a Brazilian airline. The company provides national and international flights and has around 13,000 employees and 150 aircrafts. The company has a formal research agreement with the University and, due to this, researchers had access to the employees, manuals, aircrafts and facilities. Although three different aircraft models compose the fleet, the study focused on the model produced by the national aircraft manufacturer, which accounted for the majority of the fleet (55%).

[2] Although Hollan et al. (2000) are linked to Distributed Cognition, their description of cognitive system complements the description of joint cognitive systems provided by Hollnagel and Woods (1999, 2005).