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Why did the pilots shut down the wrong engine? Explaining errors in context using Schema Theory and the Perceptual Cycle Model

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ABSTRACT

Although human error remains a dominant issue in aviation research, methods that predict human error have been criticised for not providing adequate causal explanations, rather they have focused on classification. The concept of Schemata has prevailed in the literature and has been shown to describe the contextual causes of human error. The purpose of this paper is to review the recent error literature and demonstrate that Schema Theory (as incorporated in the Perceptual Cycle framework) offers a compelling causal account of human error. Schema Theory offers a system perspective with a focus on human activity in context to explain why apparently erroneous actions occurred, even though they may have appeared to be appropriate at the time. This is exemplified in a case study of the pilots' actions preceding the 1989 Kegworth accident. Schema Theory is presented as a promising avenue for further exploration into the context of human error in aviation.

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1. Introduction

1.1. Human error and aviation

Human error is consistently implicated as a major contributor to accidents in safety critical systems, such as aviation (Amalberti, 2001; Rasmussen, 1990; Stanton and Salmon, 2009). Whilst incidents usually arise from a combination of technical, systemic and human factors, what stands out and is intensified by the media is the human element, usually as there is a desire to ascribe blame (Woods et al., 2010). Whilst accidents in safety critical systems are low probability, they are associated with an extremely high cost, i.e. loss of life (Stanton and Walker, 2011). Incident surveys in a variety of domains consistently attribute 70% of critical events to the human error category of causation (Amalberti, 2001; Baksteen, 1995; Hollywell, 1996). Whilst aviation is considered one of the safest forms of transport, it is no different to other domains in terms of percentages of human error attributions to accidents (Sarter and Alexander, 2000). Human error is considered by many to be the principle threat to flight safety (Civil Aviation Authority, 1998; Harris and Li, 2010). There will undoubtedly be human contribution to failure at some point in complex systems as a large human effort is required to maintain safety in socio-technical systems, such as a cockpit (Woods et al., 2010), therefore error is an inevitable by-product. It is likely that human action or failure to act will be found along any path to catastrophe (Flach et al., 2008). Human error is just a label or an attribution, rather than something that should be tabulated and counted (Dekker, 2002). Similarly, Lipshitz et al. (2001) argue that factors that influenced an outcome should be studied, rather than trying to quantify error rates.

The fact humans err is unavoidable (Fedota and Parasuraman, 2009) but the Human Factors literature terms contemporary thinking regarding human error as the 'new view', i.e. a move away from the 'old view' that blamed individuals and took their errors away from the context of the system they were working in (Reason, 1990; Dekker, 2006). Dekker (2006) summed up the aim of the new view of human error when he said "*human error is not an explanation of failure, it demands an explanation*" (p. 68). In other words, concluding that an accident was 'caused' by human error does not actually provide a causal explanation. Instead, Dekker (2006) argues that human error should be considered the starting point of any investigation, in an attempt to understand how people's assessments and actions made sense to them at the time. Similarly, the naturalistic decision making (NDM) world rejects the notion of faulty reasoning but instead attempts to understand why poor decisions were made. For example, saying someone used their experience is not an answer, the challenge is to identify how that experience was used (Klein, 1998). Literature over the past decade (Bennett, 2001; Dekker, 2006; Woods et al., 2010) concurs that people do not deliberately set out to make mistakes, particularly catastrophic ones. Operators, especially in safety critical domains such as aviation, are trying to do the most professional job

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they can. Decisions made by an operator are embedded in a wider context (Hall and Silva, 2008). Gaining an understanding of why they chose their actions is essential if any progress is to be made to ensure the same mistakes are not made again (Flach et al., 2008). Complex systems will often have complex explanations of why they went wrong (Dekker, 2006), which is the reason that Stanton and Walker (2011) point out that answering the 'why' question appears misleadingly simple.

There is overwhelming agreement in the literature that any research or perspective on human error needs to take the context of the system in which operators work into account (Bennett, 2001; Dekker, 2006; Woods et al., 2010). A complex system is not a single entity but is built up of interacting layers including; management, maintenance, technology and operators. Layers may have competing goals meaning trade-offs will be inevitable (Reason, 1990) and accidents often emerge due to the interdependence of systems. Baksteen (1995) likens the aviation system to a pyramid. At the topmost level is the aircraft design, the descending levels of the pyramid are activities that lead to a specific flight, including Air Traffic Services, tanking of the fuel and maintenance schedule. Baksteen acknowledges that at any level things can and do go wrong. Pilots are the penultimate level and act as a 'funnel stop' to detect the deficiencies in other levels. They can however, also add to these failures with their own mistakes which is often the reason that errors that manifest at the sharp end of an accident are often blamed on the system operator but are usually symptomatic of problems deeper within the layers of a system (Dekker, 2006). As noted by Bennett (2001) "*...crashes are the tiny tip of an iceberg composed of hundreds...of less dramatic incidents involving an aircraft or its environment*" (p. 2). It is the systemic features of an environment that will trigger the actions that made sense at the time, therefore it is essential to take this holistic view and consider the blunt end and not view error in isolation of a single person or couple of people, which arguably is easier to do (Woods et al., 2010).

Dekker (2006) argues that to answer the question of 'why' an error occurred, the understanding of the interaction between the blunt and sharp ends of a system is essential. This view point is not new, in fact Pidgeon and O'Leary (2000) argue that the interaction approach was defined by Turner (1978) a decade before much of the error research began to be generated in the 1980s. Furthermore, it is fundamental that any error research offers an explanation for why it made sense for an operator to do what they did. To provide a causal explanation requires a certain reliance on models and theories (Dekker, 2006). Within this paper it is proposed that Schema Theory and the related Perceptual Cycle Model offer a theoretical framework for understanding how the sharp and blunt ends of a system interact to lead an operator into actions that with hindsight seem to be erroneous. This paper will briefly explain what Schemata are and how the Perceptual Cycle Model has the potential to explain human error in context. The ideas will be presented through the Kegworth accident. Whilst it may be the case that there is no single primary cause of an accident (Dekker, 2006; Hall and Silva, 2008; Reason, 1990), there are still going to be causal factors that contributed to an accident more than others and from the human error perspective it is argued that Schema Theory can provide a compelling account for some, if not all, of these causes.

1.2. The origins of Schema Theory

The concept of Schemata has been in the literature for as long as the literature has been around, being traceable to the writings of Plato, Aristotle and Kant (Marshall, 1995). Though Bartlett (1932) is credited with bring the term to mainstream psychology through his studies of memory and recall which demonstrated that interactions between existing knowledge and new information created distortions with the latter. This research provided some of the first insights into the role that past experiences have at guiding cognitive processes and also modifying the message (environment). Although the ideas behind Schema Theory were adopted by some, for example Piaget (1952) based his theory of the Origins and Development of Cognition on Schemata, Schema Theory was generally considered too "mentalistic" during the dominance of Behaviorism in the early part of the 20th century (Schmidt, 1975). The dawn of the 'Cognitive Revolution' and the ideas of inferring mental processes however saw the emergence of contemporary Schema Theories in the 1970s. Neisser (1967, 1976) bought Schema Theory to prominence with his influential 'Cognitive Psychology' and 'Cognition and Reality' books, which cemented the term 'Schema' in Psychology. Empirical studies began to test Schema (e.g. Edmonds and Evans, 1966; Posner and Keele, 1968, 1970) and Schema Theory is now well established in the Psychological literature resulting in many branches including; Motor Schema Theory (Schmidt, 1975), Gender Schema Theory (Bem, 1981) and Schema Therapy in clinical practice (Young et al., 2003) and has seen many applications including driving (Hole, 2007), tool use (Baber, 2003) and Politics (Axelrod, 1973). The notion of mental representations is now well established even though there is still debate as to how these representations are developed and maintained (Woods et al., 2010).

1.3. What is a Schema?

For the purposes of this paper, a Schema will be considered as an organised mental pattern of thoughts or behaviours to help organise world knowledge (Neisser, 1976). The concept of Schemata is an attempt to explain how we represent aspects of the world in mental representations and use these representations to guide future behaviours. They provide instruction to our cognition and organise the mass of information we have to deal with (Chalmers, 2003). Our knowledge about everything can be considered as networks of information that become activated as we experience things and function according to Schematic principles (Mandler, 1984). Klein (1998) argues that it is not analytic knowledge that is required for effective decision making in a naturalistic setting of a complex socio-technical system, such as a flight deck, but instead intuition. This intuition can be in the form of metaphors or storytelling that allow the perceiver to draw parallels, make inferences and consolidate experiences. It is this area of intuition that Schematic processing will be influential; however, Klein (1998) concedes that it is this area that is less well studied by decision researchers.

When a person carries out a task, Schemata affect and direct how they perceive information in the world, how this information is stored and then activated to provide them with past experiences and the knowledge about the actions required for a specific task (Mandler, 1984). Piaget (1952) argued that Schemata were the basic building blocks of knowledge and development. Other early definitions described Schemata as mental representations of general categories (Evans, 1967a; Rumelhart and Ortony, 1977) whereas later definitions incorporated the idea of knowledge stores for more abstract concepts such as procedural knowledge of how to do things, rather than just stores for discrete categories of things (Brewer and Nakamura, 1984). In the naturalistic decision making world, Klein (1998) argues that our organisation of the cognitive world, whether that is concepts, objects or ideas, is a form of storytelling. Apart from the utilisation of Schemata, definitions also vary as to how information is represented. Schemata are can be seen as form of mental structure (Brewer and Nakamura, 1984; Rumelhart and Ortony, 1977) whereas Evans (1967b) proposes that Schemata are less of a structural entity in the mind but rather "*rules serving as instructions*" (p. 87). Whilst definitions

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