Aircraft Accident Investigations: Have we Lost Touch With the Behavioral Approach?

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Introduction

As aircraft become more technologically advanced, the causes of accidents are becoming less attributable to mechanical factors. On the other hand, human error continues to be problematic with 60%-80% of all aircraft accidents having a human error component (Federal Aviation Administration, 2004). According to Wiegmann and Shappell (1997), "Although the overall rate of aviation accidents has declined steadily during the past 20 years, reduction in human error-related accidents have not paralleled those related to mechanical and environmental factors." From this, we can surmise that it is much easier to make airplanes safer from a technological approach than from the human approach. This is a truism and the adage 'to err is human' is a testament to the problem.

The purpose of this paper is to critically analyze human error and to explore error mitigation processes. The word mitigation is purposefully used in this context because it should be clearly understood that we will never be able to completely eliminate human error; only temper it. There are a myriad of human factors that can contribute to error causation in any person at any given time. Some of these factors include fatigue, medication, vision, hearing, memory, information processing, attention, decision making, communicative ability, assertiveness, etc. Many of the latter have cognitive roots, and indeed much attention has been paid to the cognitive psychological component in aircraft accident investigations. But while the cognitive paradigm is being widely used to investigate pilot error, it begs to ask the question of whether other approaches might be as effective, or even more effective, in determining the causes of pilot error. Fuller (1997) argues that, "As cognitive psychology lurches forward it becomes progressively easier to be dismissive of its behavioral predecessor as being largely irrelevant." In fact, Wiegmann and Shappell (2001), two researchers who have conducted extensive research on pilot error, do not even hint at the behavioral approach as a source of pilot error. They cite five perspectives that include: (a) cognitive (b) ergonomics and systems design, (c) aeromedical, (d) psychosocial, and (e) organizational (Wiegmann & Shappell, 2001). While these other perspectives are highly relevant and valuable in accident investigations, the clear absence of a reference to behavioral theory should be cause for concern.

The Cognitive Approach

Cognitive psychology can be defined as, "The scientific study of the thinking mind and is concerned with, (a) how we attend to and gain information about the world, (b) how that information is stored and processed by the brain, and (c) how we solve problems, think, and formulate language" (Solso, 2001). With so much stimuli and the need to make so many decisions during the course of a flight it is no wonder why so much attention is focused on the cognitive approach when an accident occurs.

Within the cognitive realm lies one of the most problematic areas in terms of pilot error; *decision making*. In a study by Duke (1991) of 21 airline accidents occurring from 1982 through 1988, it was revealed that decision making was the number two contributing cause in the accident sample, led only by 'procedural behavior.' The magnitude of the problem is also inherent in general aviation where studies have shown that 52% of fatal general aviation pilot error accidents were caused by faulty decisions (as cited in FAA Advisory Circular 60-22, 1991, p. i). Based on these studies, there is strong support for the need to study pilot error from the cognitive paradigm. Only with an understanding of how pilots make decisions (good or bad) can we begin to improve the process.

Decisions are made as part of a three stage process: The first stage involves input (stimuli), the second stage involves information processing (making the decision), and the third stage involves the output (performing the action based on the decision). Errors can occur during any one of these stages. As an example of how this all works, let's look at a hypothetical (but not uncommon) pilot who runs off the end of the runway during a night landing. The visual runway clues are misjudged because of a wider than normal runway. At night, this can create the illusion that the pilot is lower than he or she actually is, and will try to "compensate" by either climbing or maintaining altitude when in fact he or she is on the correct glidepath and should continue a normal descent. This "overcompensation," due to the visual illusion, can lead to a longer than normal landing as the pilot overflies valuable runway while trying to get back on the proper glidepath. If the pilot lands too long, he or she may simply depart the opposite end of the runway due to the higher than normal speed and limitations imposed on the braking system.

The above example depicts a problem that began at the input stage and subsequently affected the next two stages. The misjudgment of runway width due to a visual illusion (stimuli) led to a processing error (making the decision) which led to an output error (wrong action selected). This accident had its roots in a perceptual judgment error that propagated throughout the cognitive process.

The cognitive model is but one of a number of taxonomies used to study error causation. The cognitive model is popular because it affords a deeper understanding of how an error is committed by addressing the underlying factors. For instance, an error occurs because the pilot forgets to extend the landing gear. This explains the "what" but not the "why." The "why" is addressed by looking at the underlying cognitive factors such as attention failures or decision errors (Wiegmann & Shappell, 2001).

Although it appears that the cognitive model can be used successfully to look at the underlying causes of pilot error, it is not without certain limitations. Since the core of the investigation focuses only on the pilot(s), it creates the illusion of a single point error when in fact there may have been numerous other contributing factors. These factors may include faulty equipment design, fatigue, management oversight, or organizational deficiencies. Further, framing the entire investigation by use of the cognitive perspective gives the impression that pilots are the major cause of aircraft accidents or the pilot and aircrew are the weak link in the aviation safety chain (p. 344). Clearly, this may not be the case and caution needs to be exercised when determining why aircraft accidents occur.

The Behavioral Approach

The behavioral approach analyzes how organisms learn new behaviors or modify existing ones depending on whether events in their environment reward or punish these behaviors (Plotnik, 1993). B. F. Skinner propelled behavioral psychology into a popular and widely used approach that is used today in a variety of applications (Skinner, 1989). While Skinner's theory focused on what is known as *strict behaviorism*, Albert Bandura challenged this assumption and posited that behaviorism is a combination of both cognitive processes and observable behaviors. Known as the *social learning approach*, Bandura argued that behavior is shaped not only by environmental influences but also by observation, imitation, and thought processes (Bandura, 1965).

Based on the theoretical models above, this author believes that aircraft accidents can be a result of inappropriate behavioral responses. Support for this position can be subsumed from initial pilot training experiences. For instance, a flight instructor will have a powerful effect as a role model on a student pilot. If the flight instructor models inappropriate (or unsafe) behaviors in a repeatable manner, the student will likely adopt those same practices. These behaviors may become ingrained and lie dormant for months or even years. One day, however, this pilot may revert back to one of these unsafe behaviors and put many lives at risk. Clearly, this is an example of a learned behavior that was negatively transferred from an instructor to a student. If an accident should occur, it would not appear to have the 'one size fits all' cognitive label that many openly embrace today. True, the 'trigger event' might have a cognitive implication, but without understanding what kind of underlying behavioral influences may have played a role, we are not fully able to understand the true cause of an accident.

Why, then, has the behavioral approach been largely ignored in aviation? According to Fuller (1997, p. 174), one reason is that the behavioral framework has been largely developed in an animal laboratory with limited practical application to humans. Thus, much of this approach's efficacy is based on extrapolation rather than demonstration. Second, the predictive power of the theory has been undermined by problems of definition and circularity (p. 175). One other reason is the current popularity of the cognitive approach. These seem more like excuses rather than valid reasons for discounting this approach, particularly where there is strong evidence that the behavioral component is alive and well in aviation.

"One of the primary aims associated with the introduction of human factors education to the aviation industry was the desire to change attitudes and thereby alter behavior such that unsafe acts were minimized" (Simpson & Wiggins, 1999). Support for this claim has been revealed through aircraft accident investigations (National Transportation Safety Board, 1990; Stoller, 1993). Thus, it appears that a behavioral component is still an integral part of aviation safety. Changing attitudes implies a change in behavior with a subsequent positive affect on safety. The bottom line is that we want to reinforce safe behaviors and extinguish or modify unsafe behaviors.

A study was conducted by Simpson and Wiggins (1999) that looked at attitudes toward unsafe acts in a sample of Australian general aviation pilots. The participants were 70 general aviation pilots, including 39 private and 31 commercial pilots. Forty-seven percent of the pilots had participated in some form of human factors training course; 35% of pilots had been involved in a human factors-related accident or incident. The participants filled out a 25 statement attitude questionnaire utilizing a 5-point Likert-type scale. The questionnaire also included open-ended questions for a qualitative component.

The results of the study were consistent with positive behavioral change. From the quantitative results, those pilots that had attended a formal human factors course indicated that a behavioral or attitudinal change had occurred. From the qualitative responses, comments such as "I will hardly take any risks—I ground myself more (i.e., bad weather) and will take no shortcuts" and "I now concentrate on asking factual, open questions, rather than 'reaction seeking' questions" adds further validity to human factors training interventions (p. 345).

There was a differentiator between those pilots who were involved in human-error related mishaps and those who were not. Those pilots who were involved in aircraft mishaps recorded higher scores than did pilots who had not been involved in aircraft mishaps. "This suggests that involvement in an aircraft accident or incident is associated with a shift in attitudes toward those characteristics of unsafe acts that mitigate involvement in human error-related occurrences" (p. 346).

This study did contain certain limitations. First, the sample size was relatively small. Second, the sample was drawn from one geographic location (Australia). Third, it focused only on general aviation and flight training and excluded airline operations. Hence, applicability of this study to the pilot population in general cannot be inferred. Also, it would seem to be common sense that those pilots involved in an accident or incident would be more disposed to changing their behavior in order to prevent an accident from occurring again. This supports the behavioral approach by a reactive versus proactive method (i.e., been there, done that, don't want to do it again). Whether this level of behavioral change can occur when a pilot becomes complacent after many years of accident-free flying is another question. Either way, the behavioral approach should not be dismissed.

Disparate or Complementary?

While there is a difference in the underlying theories that make up the cognitive and behavioral approaches, there should not, in this author's view, be a division between the two. Based on the evidence presented in this paper there is clearly the need to continue to use the behavioral approach from not only a training standpoint, but also from an investigative one as well. To say that this approach is "largely irrelevant" and should be "substituted" for the more vogue cognitive approach is an egregiously shortsighted view on the part of researchers and investigators. This is not to say that the cognitive approach is not effective; indeed, it is a useful tool to use to understand why pilots lose situation awareness or make faulty decisions. However, the behavioral approach can further help us understand what types of *behaviors* are conducive to errors, and ultimately try to change those behaviors. Therefore, this author feels strongly that these two approaches should be viewed as complementary

Analysis and Measurement of Pilot Error: CRM

Years of aircraft accident investigations have revealed that most crashes are not caused by technical deficiencies in pilot skills, but rather a breakdown at the interpersonal level (Federal Aviation Administration, 2004). To counter this, crew resource management (CRM) has been developing steadily since the early 1980s, when a number of key accidents highlighted the human fallibility of the aviation system (Braithwaite, 2001). Now mandatory training for airline pilots, the goal of CRM is to help pilots improve, among other things, their interpersonal (or soft) cockpit skills. Major topics in the program include Communication, Leadership and Followership, and Workload Management.

CRM training appears to be an effective tool in improving the interpersonal cockpit environment. Robert Helmreich and his colleagues, who are considered to be the most prominent researchers on the subject, have found empirical evidence that this type of training is effective for flight crews (cf. Helmreich 1984, 1997; Helmreich & Foushee, 1993; Helmreich, Wilhelm, Gregorich, & Chidester, 1990). Diehl (1991), in an analysis of six empirical and six operational evaluations for airlines, found strong evidence that CRM programs can help reduce aircrew errors and thereby prevent accidents. In another study, a survey of 30,000 airline pilots found that most pilots were satisfied with their CRM training and found it useful (Beaubien & Baker, 2001).

Since CRM (or lack of) has been the focus of many accident investigations, it makes sense that error prevention strategies and measurements are based, at least in part, on this paradigm. However, CRM has not been free of harsh criticism. In a strongly worded treatise by Besco (1998), a number of weaknesses in this methodology were cited that included:

1. Most of the original psychologists that were instrumental in the design of CRM were from the social and personality theory schools. Very few brought tools and experience from the behavioral sciences. Even fewer were experienced in practical, quantitative scientific methods developed to analyze, study, and measure flightcrew performance.
2. These psychologists suggested that theories centered on the resolution of interpersonal conflicts, sensitivity to personality differences, and the establishment of functional small group dynamics could solve poor communications and teamwork problems on the flight deck. If the CRM problems could be solved by "fixing the pilots," it was possible for top management to assume that there would be no need to change the systems, the operational practices, or the leadership principles and paradigms then in place.
3. There are numerous flaws in the design of CRM programs. [Many of these programs are developed as a "what," but lack the "why" and "how"] (bracketed item is author added).
4. Proponents of the Cockpit Management Attitude Questionnaire (CMAQ; Helmreich, 1984; Helmreich & Foushee, 1993; Helmreich & Wilhelm, 1989) cite positive score shifts and purported customer benefits of their training programs. However, the

CMAQ has not been psychometrically evaluated in the open literature for either reliability or validity. Additionally, the literature on the CMAQ contains no information or data relating to development of the initial item pool, test development metrics, or item analyses.

5. During initial CRM evaluations, data had been collected from program developers, practitioners, consultants, and CRM experts. All of these evaluators had personal, professional, and economic interests in the outcomes of their own evaluations. This once again raises the question of validity.

(Besco, 1998)

While Besco's criticism appears harsh, he does raise some fundamentally valid points. First, the original team of psychologists, with their social and personality theoretical backgrounds, may have put too much emphasis on these theories at the expense of, for instance, cognitive and behavioral approaches. Also, most of these psychologists were from Universities and government agencies and lacked a practical background in aviation per se. Second, it appears that the original concepts of CRM were developed as a "quick fix" by focusing strictly on the pilots at the expense of other, possibly more causal components, such as organizational leadership, policies, and procedures. Third, development of CRM programs can be a nebulous undertaking. While the FAA provides some guidance, it is up to each operator to develop a program that is unique to its particular operation. Unfortunately, many operators lack the knowledge or expertise to develop an efficacious CRM program at the local level. This, in turn, can have a negative (or no) affect on training transfer. Fourth, issues of reliability and validity speak for themselves. Sometimes, haste in the implementation of a measurement instrument (in this case the CMAQ) can be the problem. It might appear so in this case in that during the initial phase of CMAQ development the researchers overlooked reliability and validity issues in order to "get the product to market." Since many of the end users were not psychologists or researchers, Helmreich et al. might have thought this "minor" detail could go unnoticed or unchallenged. Fifth, the lack of objectivity in the development of the CMAQ can certainly be cause for concern. This can be analogous to a chef providing a food rating to the restaurant where he or she works. This amount of subjectivity can adversely affect the objective intent, and subsequent validity, of the questionnaire.

Analysis and Measurement of Pilot Error: LOSA

Another error classification system that is becoming increasingly popular is called the Line Operations Safety Audit (LOSA; cf. Helmreich, 2002; International Civil Aviation Organization, 2002; Klinect, 2002; Klinect, Murray, Merritt, & Helmreich, 2003). The Federal Aviation Administration (2006) defines LOSA as:

> A LOSA is a formal process that requires expert and highly trained observers to ride in the jumpseat during regularly scheduled flights to collect safety-related data on environmental conditions, operational complexity, and flightcrew performance. Confidential data collection and non-jeopardy assurance for pilots are fundamental to the process.
>
> (Federal Aviation Administration, 2006)

As with CRM, airlines are embracing LOSA as a proactive approach to safety (addressing errors before they lead to critical incidents). By creating a database from these line audits, airlines are better able to look for trends or problem areas and initiate countermeasures if required. As an example, if 5% of observed crews make a callout error during the approach and landing phase, there may be a problem with those crews. However, if 50% of observed crews make the same error, then the evidence suggests a problem with the callout procedure (p. 3).

While on the surface it appears that real-time observations by trained observers would be a good idea, the method is not without its limitations. Dekker (2003) suggests that error classification itself may be too ambiguous and therefore not reliable. He cites that, since 1997, more than half the human errors detected by observers in 1,426 commercial airliner flights were never detected (or classified as errors) by the flightcrews themselves (cf. Croft, 2001). Perceptions of an error can vary widely between two people. What one person sees as a minor error another person can see as a potentially life threatening mistake. The person who commits the error is going to have a subjective view while an observer will ostensibly have an objective view. Will these two disparate views help or hurt the cause? Could this cause overreporting or underreporting? Are there minimum thresholds established for reporting an error?

Thus, while LOSA can provide useful data on the surface, there are some scientific principles that need to be ironed out in order for the model to become whole. "Without clear definitions, or models of error, error counting amounts to pseudoscience or numerology" (Dekker, 2003).

Another potential problem with the LOSA model is the direct observation method. There will likely be variability and potential bias in the observers. Although Helmreich and Klinect, the primary developers of LOSA, will argue that this is not a factor (as cited in Federal Aviation

Administration, 2006), it would be hard to assume that observers in the cockpit, who work for the same airline, may not influence the behavior of the pilots in some way (i.e., the pilots might be on their best behavior). What if the pilots are friends with the observer? What if the observer despises the pilots? True objectivity still remains questionable.

Analysis and Measurement of Pilot Error: Human Factors

Wiegmann and Shappell (1997, p. 67) suggest that although human error is involved in nearly all aviation accidents, most accident reporting systems are not currently designed around any theoretical human-error framework. As a result, Wiegmann and Shappell argue that, "Postaccident databases generally are not conducive to traditional human factors analysis, making the identification of interventions extremely difficult."

When a pilot commits an error, and is reported into a database, it then becomes an important piece of information. Errors are reported in an attempt to prevent the same type of error from happing again, possibly to another person. While this method works superficially and can be somewhat effective, there appears to be very little offered in the way of specific theoretical tie-ins to error causation. Numerous taxonomies exist and are used piecemeal depending on the theoretical orientation of the researcher or person interested in the topic (Senders & Moray, 1991).

Regardless of the convoluted taxonomies, Wiegmann and Shappell did identify three prominent frameworks. These included:

1. A traditional four stage model of information processing.

2. A model of internal human malfunction derived from Rasmussen's (1982) Skills-Rules-Knowledge model.
3. A model of unsafe acts as proposed by Reason (1990).

   (Wiegmann & Shappell, 1997)

The four stage model of information processing focuses on stimuli, pattern recognition, decision and response selection, and response execution (Wickens & Flach, 1988, as cited in Wiegmann & Shappell, 1997). This is the cognitive model that was explained earlier and is widely used today to understand pilot error.

Rasmussen's (1982) Skills-Rules-Knowledge framework divides error into three categories: (a) *Skill-Based*, where a person is able to perform very effectively by using "pre-programmed" sequences of behavior which do not require much conscious thought (which can lead to "complacency-type" errors), (b) *Rule-Based*, where a person operates from a set of known rules (which *may or not* be correct for a particular task) , and (c) *Knowledge-Based*, where a person has a deficiency, or an improper application of, knowledge to perform a task.

Reason's (1990) model of unsafe acts is based on whether a behavior is intentional or unintentional. Unintentional acts are considered to be slips, lapses, and attentional failures. Intentional acts are classified as either mistakes or violations and the distinction between the two is important because unintentional acts are considered to be part of "everyday human error" while intentional acts may be indicative of deeper problems such as procedures, training, knowledge, etc.

Space constraints do not allow for a more in-depth discussion of these models. Therefore, the basic concepts were presented in order for the reader to gain at least a rudimentary knowledge of Wiegmann and Shappell's suggested frameworks. This author agrees that their framework tripartite could be useful in understanding pilot behavior when analyzing postaccident data. This would be a better alternative to the analytical methods now in place that appear to meander among various frameworks, some of which may not even be relevant to error causation. In any case, a proper link between accidents, errors, and their theoretical frameworks can help to provide more effective ways to reduce pilot error by providing a better understanding of the otherwise hidden underlying causes.

Conclusion

This paper presented two psychological models that can be applied to pilot error. The cognitive approach is the popular choice at the moment and many accident investigators concentrate on "human information processing" in their search for answers. However, the behavioral approach has not seen as much popularity and has even been labeled as "irrelevant." This author presented arguments from both sides and posits that both of these approaches are equally important and should be viewed as complementary rather than disparate. However, an admonition should be put forth that while both of these approaches look at human error on an individual basis, they do very little to address other factors such as organizational culture, leadership deficiencies, and standard operating procedures. Without considering these important potential influences in the accident chain, an investigation cannot be considered substantive and complete. The cognitive and behavioral approaches only address the pilot and his or her actions; they do not take into account any organizational pathogens that may influence those pilot's erroneous actions.

Finally, this paper looked at analysis and measurement of pilot error from CRM, LOSA, and human factors frameworks. On the surface, these programs appear to be highly effective in quantifying and remediating pilot error. However, evidence suggests that there are inherent limitations in all of these frameworks and a true picture of pilot error is much more difficult to attain than one would be led to believe; the largest cause for concern being error definition and instrument validity.

In sum, any proactive step to improve aviation safety is a step in the right direction. We just need to be aware of the limitations and shortcomings that are associated with scientific research. And most importantly, we need to understand that behavioral psychology is alive and well and should not be considered "irrelevant" when investigating pilot error.

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