A Review of the Literature Pertaining to Decision Making in Aviation

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TABLE OF CONTENTS

Abstract

A review of the literature in aviation decision making was conducted to explore some of the theoretical and practical applications that could be beneficial to pilots. Improper decisions have been implicated in more than 50% of general aviation accidents. While there is an increased research component in this important domain, there still appears to be an overall lackadaisical attitude in fully addressing aeronautical decision making skills during initial pilot training where it will be most beneficial. Technical skills alone are just not enough to make a safe pilot. It is intended that this paper will shed additional light on how pilots make decisions and how those decisions can be erroneously influenced by basic cognitive limitations.

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Case 1
14 CFR Part 91: General Aviation
Injuries: 1 Serious

The pilot's improper decision to attempt a landing with an excessive tailwind, which resulted in an inadvertent stall while attempting to climb during a go-around. A factor related to the accident was the tailwind conditions and the rising terrain beyond the runway. (NTSB Accident Identification # NYC04LA081, 2005).

Case 2
14 CFR Part 91: General Aviation
Injuries: 6 Fatal

The pilot's improper decision to continue VFR flight into IMC conditions and his failure to maintain terrain clearance, which resulted in controlled flight into terrain. Factors were night, snow and a low ceiling. (NTSB Accident Identification # NYC04FA092, 2004).

Case 3
14 CFR Part 91: General Aviation
Injuries: 3 Fatal

The pilot's failure to maintain aircraft control during the missed approach. Factors to the accident were; the pilot's improper decision to attempt the approach in weather conditions below the approach/landing minimums, the weather, the pilot's lack of multiengine instrument experience, and spatial disorientation by the pilot. (NTSB Accident Identification # CHI00FA080, 2001)

Introduction

There is probably no better way to start a paper on the topic of decision making than with a few salient case examples. These cases were randomly selected from the NTSB (National Transportation Safety Board) aviation accident database (2005a) by using the keywords 'improper decision.' From the hundreds of results returned, three were randomly selected as case examples. All three involved general aviation (GA) aircraft being operated under Part 91 of the CFRs (Code of Federal Regulations). Further analysis revealed that of the three accidents as an amalgam, improper pilot decisions were determined by the NTSB to be the probable cause of nine fatalities and one serious injury. From these data, one can surmise that flawed decision making in a high risk environment can have serious consequential effects on life and property.

Poor decision making is not indigenous to general aviation either. 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 population of the study contained seven fatal accidents where 371 persons were killed. There were 14 accidents during landing and seven during takeoff. Nine aircraft were destroyed (p.1).

Piloting an aircraft is a dynamic and challenging experience replete with a seemingly endless string of choices, decisions, and actions; from well before a flight begins to after the aircraft is chocked at the ramp. There are many factors that influence pilot decisions; these include experience level, personality type, motivation, peer pressure, time pressure, etc. Accordingly, these factors may affect decision making either singly or concomitantly.

In 1991, the FAA issued Advisory Circular (AC) 60-22, which addressed Aeronautical Decision Making, or ADM. The purpose of the Advisory Circular was to, "Provide a systematic approach to risk assessment and stress management in aviation, illustrate how personal attitudes can influence decision making, and how those attitudes can be modified to enhance safety in the cockpit." (p. i). The underlying cause for issuance of the AC was that too many pilot errors were being committed as a result of poor decisions or judgment and less because of technical or mechanical errors.

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). The FAA claimed that specific training in ADM could make a difference; and it appears that they were correct. In six independent studies, where student pilots were issued training materials on ADM in conjunction with the standard flying curriculum and compared to a control group that did not receive the ADM supplement, the pilots who had received the ADM training made fewer in-flight errors than those who had not received ADM training (as cited in FAA Advisory Circular 60-22, 1991, p.i). The differences were statistically significant and ranged from about 10%-50% fewer judgment errors. While these numbers seem impressive and encouraging, it should be noted that this author did not have access to the original studies or methodologies and therefore cannot say for certain that the studies were truly valid and reliable. However, it seems likely that the studies do have meaningful value and would be a good indicator of ADM efficacy.

In the real world, pilots make hundreds of decisions during the course of a flight. Some of the decisions are small and benign while others are major and potentially consequential. Good decisions typically outnumber bad decisions, but just one bad decision can have a profound and disastrous effect. As an example, go back to Case #1. This accident occurred during the final phase of flight (landing). The pilot obviously made enough good (or at least proper) decisions to complete the flight up to that point. However, when the decision had to be made that involved landing with an excessive tailwind, the pilot made a bad choice. That one choice caused an inadvertent stall during the go-around and the subsequent impact with rising terrain. The pilot sustained serious injuries.

But why would a pilot make such a flawed decision to begin with? What kind of thought processes are involved in a situation such as this? Can these decision errors truly be mitigated by ADM training? This paper will seek to answer these and other questions.

The Five Hazardous Attitudes

The Federal Aviation Administration postulates that there are five hazardous attitudes that can negatively affect pilot decision making (Chap.3, p.11). While these attitudes can be applied to just about any situation (e.g., driving a car, operating a motorboat, or performing surgery), aviation has been an advocate of pointing out these hazardous attitudes by making them available through non-technical training, such as ADM courses and advisory circulars.

The five hazardous attitudes are matched with antidotes, which according to the FAA, should act as a countermeasures. A summary of these attitudes is included here:

1. Antiauthority- ("Don't tell me!"). Pilots might not like anyone telling them what to do. Further, they might regard rules, regulations, and procedures as silly or unnecessary. The antidote for this attitude is: *Follow the rules. They are usually right.* (Chap.3, pp.11-12).
2. Impulsivity- ("Do something quickly!"). Pilots might be impulsive and perform actions quickly but not necessarily correctly. By being impulsive, the likelihood of making a proper decision, when confronted with alternatives, is diminished. The antidote for this attitude is: *Not so fast. Think first.* (Chap.3, pp.11-12).
3. Invulnerability- ("It won't happen to me"). A feeling of invulnerability might lead a pilot to believe that accidents only happen to other people. Accordingly, pilots who think this way are more likely to take chances and increase risk. The antidote for this attitude is: *It could happen to me.* (Chap.3, pp.11-12).
4. Macho- ("I can do it"). This attitude might make the pilot feel that he or she is better than everyone else. The term "she" is also purposefully used here because, although macho is regarded as a male characteristic, women are equally susceptible. Pilots with this type of attitude will try to prove themselves by taking risks in order to impress others. The antidote for this attitude is: *Taking chances is foolish.* (Chap.3, pp.11-12).
5. Resignation- ("What's the use?"). Resignation can occur when a pilot feels that he or she may not have a great deal of influence on outcomes. When things go well, the pilot is apt

> to think that's good luck. When things go badly, the pilot may feel that someone is "out to get them," or attribute it to bad luck. Another problem with this attitude is that a pilot might go along with unreasonable requests just to be a "nice person." The antidote for this attitude is: *I'm not helpless. I can make a difference.* (Chap.3, pp.11-12).

In ADM training, pilots are not only introduced to, and educated on, the five hazardous attitudes, but they are also able to answer a questionnaire that provides them with feedback on their own attitudes. Assuming the pilot is being honest and open with his or her answers, there are many valuable insights that can be gained that would not normally be measured. According to Jensen (1995), pilots must first be aware of their hazardous attitudes and then they must be motivated away from those attitudes.

This author feels that the inclusion of the five hazardous attitudes in ADM training does have a positive affect for the edification of pitfalls in personality. However, there are a few limitations that should be recognized when conducting ADM training and assessment.

First, one needs to keep in mind that these attitude questions are broadly presented and subjective interpretation and biases can run rampant. This can be exacerbated by the use of self-reporting questionnaires where the results may be confounded by the test-takers' propensity to answer the questions in a way they believe to be true or what they think should be true or correct (Leedy & Ormrod, 2005).

Second, interpretation of the results might misleadingly infer a stable and enduring behavioral attitude or trait. But in reality there are situational variables that might trigger one or more of the five hazardous attitudes at any given time. An example of this might be a pilot who normally follows the rules and regulations to the letter but one day needs to break a rule in the interest of safety. "Wait a minute", you say, "This statement appears to contradict itself." Yet on any given day, if you pose this question to a pilot and try to elicit an honest answer, there is a good chance they will admit they have had this dilemma, and it was likely due to an unexpected situational variable. So does that make the pilot an antiauthority rule breaker?

Third, researchers have suggested that there is a need to modify the five hazardous attitudes concept to more thoroughly reflect other human behaviors such as "loss of face" (Murray, 1999). Based on follow up validation testing of the Embry-Riddle Aeronautical University manuals in Australia (the five hazardous attitudes concept was developed by ERAU) Telfer (1987, 1989) proposed that a sixth hazardous attitude, *deference,* be added to the list. The genesis of the additional attitude actually had its roots in the fifth hazardous attitude, *resignation.* Originally, resignation was given the label *external control* since an external locus of control could be contributory to resignation (Lester & Bombaci, 1984). However, "resignation" was subsequently retained for the label. This proved somewhat shortsighted because "deference" is more in line with the original label of external control than the present label of "resignation" (Murray, 1999, p.406). That all said, Telfer suggested that deference be added as a sixth hazardous attitude and be defined as, "Pilots who bow to the pressure to conform to their peers or to authority." In contrast, Murray suggests that the hazardous attitude "resignation" should be eliminated completely and replaced with "deference" in order to maintain the "attractive simplicity of the existing concept with only five hazardous attitudes (p.408).

One other interesting criticism of the five hazardous attitudes concept was discussed in Murray's report. This pertained to the concept of "loss of face" and the *macho* attitude. *Face* can be defined as, "The positive social value a person effectively claims for himself by the line others assume he has taken during a particular contact" (Goffman, 1955). People always want to look good in front of others and a loss of face can have a potentially negative impact on decision making. Therefore, Murray suggests that loss of face be incorporated into the existing hierarchy (Murray, 1999, p.408). The question is how this can be done while still maintaining the "attractive simplicity." Since fear of face is related to the macho attitude, a rewording of this attitude could be effective both in elucidating loss of face as well as maintaining the parsimony of the model. To that end, Murray recommends including the hazards of saving face in the macho attitude domain and to redefine that domain as follows:

Macho- This attitude is found in pilots who continually try to prove (or show) themselves (as good as or) better than others. They tend to act overconfident and attempt difficult tasks for the admiration it gains them. When faced with threats to their competence, they are reluctant to accept or admit their shortcomings by seeking assistance, either within the cockpit from fellow crew members or externally from air traffic control or other aircraft. Their fear of losing face can be carried to the extreme, where it exceeds their fear of loss of life itself (Murray, 1999, p.408).

Even though the five hazardous attitudes concept has come under some criticism, this author opines that it is still an effective and simple way to address and assess pilot attitudes that can have consequential effects on the safety of flight. As of today, this model is the best we've got, and with some minor future modifications, should be around for a while.

The DECIDE Model

The DECIDE model, also appearing in the FAA ADM Advisory Circular 60-22 (Chap.5, pp.21-22), is also a useful tool to help pilots with a pragmatic approach to decision making. The six elements of the model consist of the following:

1. *Detect.* The decision maker detects the fact that change has occurred.
2. *Estimate*. The decision maker estimates the need to counter or react to the change.
3. *Choose*. The decision maker chooses a desirable outcome (in terms of success) for the flight.
4. *Identify.* The decision maker identifies actions which could successfully control the change.
5. *Do*. The decision maker takes the necessary action.
6. *Evaluate.* The decision maker evaluates the effect(s) of his action countering the change.

(FAA Advisory Circular 60-22 Chap.5, pp.21-22)

The benefits of the DECIDE model are fairly obvious. First, during ADM training, the pilot is introduced to a simple acronym that is easy to remember. Second, once committed to memory, its use as a "checklist" can give the pilot some quick guidelines for making a decision. This can be especially helpful in a stressful situation or when concurrent, multiple decisions are required. Third, DECIDE is a continuous loop process. The process is continuously recycled as the pilot is confronted with new decision choices during the course of a flight.

One study that looked at the effectiveness of the DECIDE model was conducted by Jensen, Adrion, and Maresh (1986). Conducted as more of an exploratory investigation, Jensen and colleagues used a sample of 10 private pilots with a range of 60 to 233 flight hours. Five of the subjects (three males and two females) were used as experimental subjects (received the DECIDE training), and the other five (four males and one female) were used as the controls (received no training). The experience levels of the experimental and control subjects were very similar.

The experimental subjects were taught to use the DECIDE model in marginal aviation decisions in a five-hour interactive lecture that included four case studies. Three of the case studies focused on previous accidents that occurred as a result of poor decisions. The fourth case study was used as a representation of a successful outcome based on good decisions. After the lecture, the pilots prepared to make a simulated cross-country flight from Port Columbus, Ohio to Frederick, Maryland. The motivation for the flight was established via reading the subject an indoctrination story putting them in the position of needing to arrive in Frederick to compete in a spot landing contest (Jensen, 1995, p.106).

During the simulated flight there were three experimenter-induced changes programmed into the scenarios as checkpoints to observe the decision making process. These included 1) the failure of the attitude indicator, 2) the introduction of carburetor ice, and 3) deteriorating weather. Each of these changes occurred at 10 minute-intervals as the flight progressed. At each of these checkpoints the experimenter noted whether or not the subject decided to turn around and return to Columbus. Subjects were free to decide when to make the turn (p.106).

Each of the four experimental subjects who chose to fly landed safety after turning around. However, each of the three control subjects who chose to fly, crashed; one of these could not handle the attitude failure, and two failed to diagnose correctly the carburetor ice problem. The experimental subjects had no trouble handling either of these problems (p.108).

The results tend to support the hypothesis that the DECIDE model can be potentially effective in improving decisions. The word "potentially" is used because there were a number of limitations in this study. These limitations included 1) this was only an investigative (prospective) study, 2) the sample size was very small, 3) the subjects were all low time private pilots, and 4) the study was conducted in a simulated flight environment. While this is a simpler and safer way to conduct this type of study, actual decisions made in a real airplane on a real flight plan, without being observed by an experimenter, could be significantly different. Additionally, there does not appear to be any substantive follow-up research on the DECIDE model. Empirically based conclusions would certainly lend more credence to the efficacy of the model.

That all being said, there is still no doubt that the DECIDE model is well-suited for pilots as a means of recognizing, evaluating, and responding to the myriad of decisions that need to be made during the course of a flight.

Judgment

Decision making is typically offered concomitantly with the topic of judgment in most ADM courses since they are both highly related to one another. One question that has incessantly been debated is, "Can judgment be taught?" On the surface it seems like it cannot. Many people would opine that judgment, similar to personality traits, is something that is engrained and difficult to change. Some people "naturally" have good judgment, while others have poor judgment, and then there are those in the middle. So the question of whether judgment can be taught is a good one indeed. According to Jensen (1995), judgment *can* be taught and there is a fair amount of research to support that claim (Thorpe, Martin, Edwards & Eddows, 1976; Berlin et al., 1982;

Buch & Diehl, 1982; Telfer, 1989; Connolly, Blackwell, & Lester, 1987; Jensen, Adrion, & Maresh, 1986).

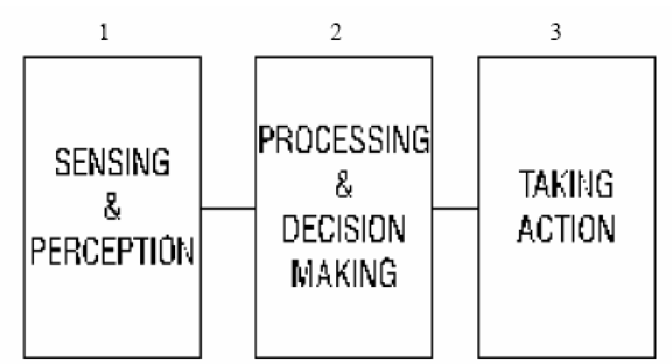
To make sure there is consistency in the use of the word 'judgment,' we first need to operationalize its meaning. Used in this context, judgment means, "The capacity to assess situations or circumstances and draw sound conclusions; good sense" (Answers.com, 2005). Further, as it relates to pilots, it is important to distinguish between perceptual and cognitive judgment (Jensen, 1995) even thought the two can be inextricably linked. Perceptual judgment can be thought of in terms of how a pilot perceives things such as distance, the width of a runway, or even the height of the copilot. This type of judgment is based on perceptual clues and uses a combination of past experiences (or schemas) and best guesses of estimation. Cognitive judgment occurs when we *input* available information (or stimuli), *process* that information, and then *take action* (or perform an output). Also known as human information processing, it is obvious that cognitive judgment is analogous to a computer, and there are opportunities for errors to occur at any stage. These errors and their possible causes can be categorized as follows:

Type of error	**Possible causal factors**
Failure to detect signal	Input overload Adverse environment
Incorrect identification of signal	Lack of differential cues Inappropriate expectation
Incorrect signal recalled	Confusion in short-term memory Distraction before task completed
Incorrect assessment of priority	Values inadequately defined Complex evaluation required
Wrong action selected	Consequences of action misjudged Correct action inhibited
Incorrect execution of action	Clumsiness due to excessive haste Selection of wrong control device

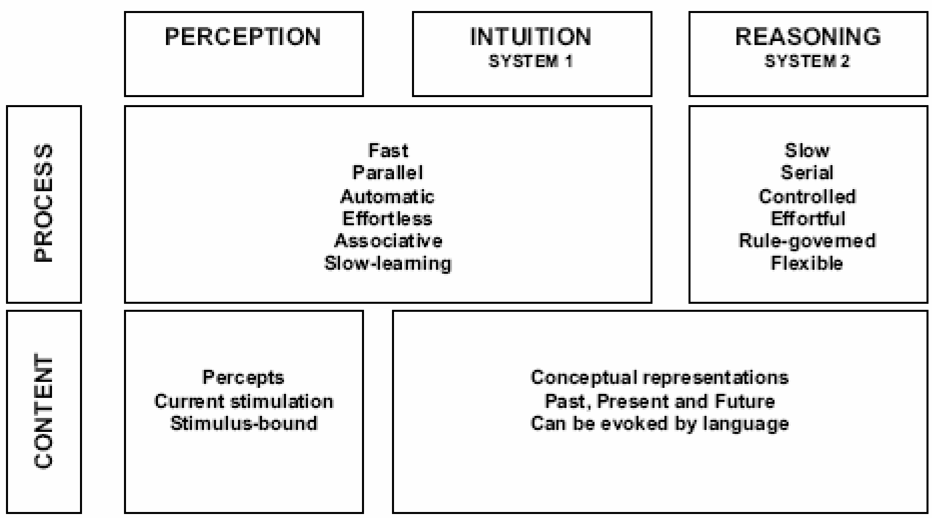
(Adapted from Edwards, 1988, p.20)

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, and this goes back to perceptual judgment, 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 begins at the input stage and subsequently affects the next two stages. The misjudgment of runway width due to a visual illusion (incorrect identification of signal) led to a processing error (incorrect assessment of priority) which led to an output error (wrong action selected). This accident had its roots in a perceptual judgment error that propagated through the cognitive decision process. The following illustration shows how this process works graphically.



Another model, offered by Kahneman (2002), goes a little deeper into the process of judgment, and because of its theoretical importance, will be mentioned briefly here. Kahneman suggests that judgment processing consists of two systems; System 1, or Intuition, which is fast, parallel, automatic, effortless, associative, and slow learning; and System 2, or reasoning, which is slow, serial, controlled, effortful, rule-governed, and flexible. These describe the way information is processed within each system and clearly shows the differences in cognitive effort required by each.



(Adapted from Kahneman, 2002, p.451)

One of the functions of System 2 is to monitor the quality of both mental operations and overt behavior (Gilbert, 2002; Stanovich & West, 2002, as cited in Kahneman, 2002). In anthropomorphic terms, explicit judgments that people make (whether overt or not) are endorsed, at least passively, by System 2. It is suggested that the monitoring by System 2 is quite lax, and allows many intuitive judgments to be expressed, including some that are erroneous (Kahneman & Frederick, 2002).

Turn your attention back to Case #3 in the beginning of this paper. We are going to concentrate specifically on the following extraction: "The pilot's <u>improper decision</u> to attempt the approach in weather conditions below the approach/landing minimums" (NTSB Accident Identification # CHI00FA080, 2001). Here is a classic example of flawed cognitive judgment. The pilot may have rationalized that descending below minimums had worked out before and therefore should not be a problem this time. Also knowing that there would be a small chance of being caught and violated by the FAA for breaking a rule (landing minimums) may have contributed to a false sense of security. Weather decisions appear to be the some of the most problematic for pilots. This, as well as an expansion of decision theory, will be covered shortly.

For now, we will readdress judgment as a human characteristic and look at some of the results of judgment training research as a way to prevent accidents, like the one above, from continuing to occur at such an alarming rate.

In the first study of its kind, an experiment was set up to measure the effects of judgment training for private pilot candidates at Embry-Riddle Aeronautical University (Berlin et al., 1982). An experimental group of 25 pilots were taught how to identify the five hazardous thought patterns through lectures, discussions, and customized training manuals. A control group of 25 equally experienced students received the same flight and ground instruction but received no judgment training (as cited in Jensen, 1995, p.98).

Both groups were then tested for issuance of their private pilot certifications, which included a judgment analysis during preflight inspection and while on a short cross country flight (malfunctions were actually "planted" for students to find). Results showed that students who had been given judgment training made 16% fewer judgmental errors than those in the control group who had not received the specialized judgment training (Berlin et al., 1982, as cited in Jensen, 1995, p.99). One of the major limitations to this study was that flight students who knew they were going to be tested on judgment skills may have demonstrated more use of these skills as a byproduct of being observed. This confound was addressed in the next study of interest.

Buch and Diehl (1982) conducted a similar study using Canadian Air Cadets from two different schools. The pilots were kept separate from each other to avoid cross-contamination (or exchanges) between the groups. The two groups (experimental and control) were shown to be equal in skills and knowledge both prior to and after training for the private pilots license (as cited in Jensen, 1995, p.99).

From a methodological standpoint, this study was similar to the one conducted by Berlin and colleagues. There were 25 subjects in the experiment group and 25 subjects in the control group. Once again, the experiment group received judgment training while the control group did not. There were two notable differences however; the first was that that all of the participants had already received their private pilot licenses. The second was that the pilot subjects were approached by a judgment examiner posing as photographer who wanted aerial pictures and who was also willing to pay for the flight. All students took the "photographer" up on the offer. During the flight (including preflight) the deceptive "photographer" was carefully recording decisions being made by the pilot. Eighteen different items were scored (p.99).

The results were also consistent with the previous study. Of the 18 items scored, the judgment trained students performed equal or better than the control group in every case. Thirteen of the 18 decision categories were significant ($p < .05$). Overall, the judgment trained pilots scored 83.5% correct decisions while the conventionally trained pilots scored 43.5% correct decisions (p.100). The use of deception in research is arguably a controversial subject. However, in a benign experiment such as this, deception can help to address the "observer effect" confound and improve the overall validity and reliability of the results.

There were a few other studies that supported the concept of learning and applying judgment in aviation operations, but due to space limitations, cannot be included here. Also, it appears that many of the initial studies that were associated with the validation of the DECIDE and Five Hazardous Attitudes models did not receive empirical support as there was a lack of reference to these models in more recent literature searches. This might be an area that warrants further attention.

Decision Research, Theories, and Practice

Now that judgment has been touched on, and some studies have been reviewed, let us now turn our attention to decision theory. The intent of this section is to discuss some of the general theoretical models and tie them to airplane pilot decision making. The three case examples listed in the beginning of this paper will be used as an anchor for many of the upcoming discussions.

An operational definition of 'decision making' is, "The cognitive process of selecting a course of action from among multiple alternatives" (Answers.com, 2005a). Humans make hundreds of decisions every day. From waking up in the morning to going to sleep at night, humans must make decisions among alternatives all day long. An airplane pilot not only has these "regular" daily decisions, but also takes on the additional and sometimes critical decisions encountered during the course of flight. There are numerous factors that can affect the decision making process; these can include fatigue, stress, medication, anxiety, training, experience, knowledge, noise, vibration, etc. While some of these are more grounded in psychophysiological effects, there are also some cognitive theoretical constructs that can affect decision making as well.

There is a large literature that addresses decision making, both in the global sense, as well as in aviation itself. So important is this science that NASA has an entire division devoted to studying, among other things, pilot cognition at its Ames Research Center in California (NASA Ames Research Center, 2005). Since so many accidents are attributed to improper decisions, research has been brisk, and the studies numerous.

Statistically, there is good reason to emphasize research in cognition and pilot decision-making. An NTSB (1994) analysis of 37 accidents, where crew behavior was a causal factor, concluded that tactical decision errors contributed to 25 of the accidents, or about *two out of three cases* (as cited in Orasanu & Martin, 1998). Here it needs to be pointed out that these statistics represent a study of airline accidents (i.e., it did not include general aviation). In general aviation, however, these numbers are fairly transferable although the less structured environment of general aviation may contribute to a slightly higher rate of tactical decision errors.

Weather Decisions

To add a practical side to this, let us again review Case # 2. This case is highly salient from both a theoretical as well as practical standpoint (this type of decision-based accident occurs frequently in general aviation).

> **The pilot's <u>improper decision</u> to continue VFR flight into IMC conditions and his failure to maintain terrain clearance, which resulted in controlled flight into terrain. Factors were night, snow and a low ceiling.** (NTSB Accident Identification # NYC04FA092, 2004).

Continuing VFR (visual flight rules) flight into IMC (instrument meteorological conditions) weather has been studied extensively as it pertains to pilot decision making (Wiegmann, Goh, & O'Hare, 2001; O'Hare & Smitheram, 1995; Knecht, Harris, & Shappell, 2005; Hunter, Martinussen, & Wiggins, 2003). If you are a non pilot this basically means that a pilot who is not rated to fly into bad weather continues to do so knowing that the outcome could be consequential. It is also a violation of the regulations. Further, many pilots who are not rated to fly in bad weather may take unnecessary risks by taking off into conditions that may be beyond his or her capabilities "hoping that the weather will improve or at least won't get worse."

Inefficient or ineffective in-flight weather-related decision making remains a significant causal factor associated with general aviation fatalities in the United States (Aircraft Owners and Pilots Association, 1996). VFR into IMC accounts for 10% of the overall number of crashes involving general aviation operations. However, 82% of these accidents involved fatalities (Hunter, Martinussen, & Wiggins, 2003).

In a study by Knecht, Harris, and Shappell (2005), influences of ground visibility, cloud ceiling height, financial incentive, and personality were tested on 60 general aviation pilots' willingness to take off into simulated adverse weather. Results suggested that pilots do not see "weather" as a monolithic cognitive construct but, rather, as an interaction between its separate factors. This was supported by the finding that the multiplicative statistical effect of visibility and ceiling could better predict takeoff than could the linear effect of either variable considered separately. Also found was a statistical trend toward financial incentive being able to predict takeoffs. However, none of the 10 personality tests (incorporating over 500 separate response items) could predict takeoff (p.i).

Another study applied behavioral decision theory to pilot decision making as it related to VFR into IMC (O'Hare & Smitheram, 1995). The purpose of the study was to determine whether a descriptive theory of decision making could be applied to pilots' decisions about whether to continue a flight into deteriorating weather. The study was grounded in prospect theory which suggests that when situations are viewed in terms of gains, people are risk averse, but when situations are viewed in terms of losses, people are risk seeking. Computer simulated scenarios of cross-country VFR flights were presented to participants who had to decide whether they would continue with the flight. The study investigated three questions. First, do pilots normally frame such decisions in terms of gains or losses? Second, what factors are considered relevant by pilots when making such decisions? Third, can a pilot's decisions about whether to continue a flight be manipulated by the framing of the problem? It was hypothesized that pilots who were encouraged to make their decision in terms of anticipated gains from their current position would make more risk-averse or cautious decisions than pilots who were concerned about minimizing past costs. Results showed that participants tended to select the gains frame (e.g., personal safety) rather than the losses frame (e.g., loss of time, money, and effort) as the way they would naturally consider the decision of whether to continue with the flight. Participants rated social influence as the least important factor affecting their decisions. Pilots who viewed the decision from a gains framework were significantly less likely to press on into deteriorating conditions than pilots who viewed the decision from a loss perspective (p.351).

Due to its relevance, an amplification of prospect theory is appropriate. In prospect theory, the value function for losses is steeper than that for gains, because losses "loom larger" than gains (Plous, 1993). Prospect theory also predicts that preferences will depend on how a problem is framed. According to Plous:

> If the reference point is defined such that an outcome is viewed as a gain, then the resulting value function will be concave and decision makers will tend to be risk averse. On the other hand, if the reference point is defined such that an outcome is viewed as a loss, then the value function will be convex and decision makers will be risk seeking (Plous, 1993, p.97).

This theory gained support in a study by Kahneman and Tversky (1979). Kahneman and Tversky presented 70 subjects with the following problems:

> **Problem 1.** In addition to whatever you own, you have been given $1000.00. You are now asked to choose between Alternative A and Alternative B.
>
> **Alternative A:** A 50% chance of gaining $100.000
>
> **Alternative B:** A sure gain of $500.00

Of the 70 respondents who were given a version of this problem by Kahneman and Tversky, 84% chose the sure gain. According to Plous, this makes sense because the value function rises more from $0 to $500.00 than from $500.00 to $1000.00.

> **Problem 2.** In addition to whatever you own, you have been given $2000.00. You are now asked to choose between Alternative C and Alternative D.
>
> **Alternative C:** A 50% chance of losing $1000.00
>
> **Alternative D:** A sure loss of $500.00

Presented this way, nearly 70% of those surveyed chose the risky alternative. In this case, and again according to Plous, risk seeking makes sense when losses are at stake because more value is lost from $0 to $500.00 than from $500.00 to $1000.00.

The two problems are numerically equivalent and yet, when presented in different ways, each elicits different choices. This should help to clarify the concept of framing and how risk seeking and risk aversion can be affected by the presentation of the problem.

In the real world flight environment, O'Hare and Smitheram (1995) suggest that decision frames may be induced by the proximity of the pilots' goals, such as the destination airport. As goal achievement gets closer the "sunk cost" effect might be more likely. The sunk-cost effect specifies that if more has been invested in a certain course of action, the less likely this course of action will be abandoned than if less were invested (Kahneman & Tversky, 1982, as cited in Wiegmann, Goh, & O'Hare 2001). This hypothesis was tested by O'Hare and Owen (1999, as cited in Wiegmann, Goh, & O'Hare 2001) by requiring pilots to fly a simulated cross country flight in which they encountered adverse weather either early or late into the flight. The prediction was that pilots who encountered the weather late into the flight (long condition) would more likely continue because of the greater investment of time than those who encountered the weather earlier during the flight (short condition). But, the study failed to support the sunk-cost hypotheses in that the majority of the pilots in both the short and long conditions chose to divert the flight (p.3). However, there were some concerns about the methodology of the study and therefore the validity of the results may have been questionable. Because of this, Wiegmann and colleagues set out to expand the study and account for some of the methodological shortcomings.

Wiegmann, Goh, and O'Hare (2001) investigated the effects of distance traveled and flight experience on pilots' decisions to continue VFR flight into adverse weather conditions. In their study, Wiegmann and colleagues looked at pilots' decisions to continue or divert from a VFR flight into IMC during a dynamic simulation of a cross-country flight. Pilots encountered IFR conditions either early or later into the flight and the amount of time and distance pilots flew into the adverse weather prior to diverting was recorded. Results revealed that pilots who encountered the deteriorating weather earlier in the flight flew longer into the weather prior to diverting, and had more optimistic estimates of weather conditions, than pilots who encountered the deteriorating weather later in the flight. Both the time and distance traveled into the weather prior to diverting were negatively correlated with pilots' previous flight experience. These findings suggested that VFR flight into IMC may be due, at least in part, to poor situation assessment and experience rather than to motivational judgment that induces risk-taking behavior as more time and effort is invested in a flight (p.1).

As you can see by now, problems in decision making, as they pertain to weather, can be a complex domain. Some would argue that decisions are based on prospect theory with its associated gains and losses (frames) while other might argue that the decisions are based more on poor situation assessment and experience. Still other views point to more of a narrow-minded type of mindset, or a Plan Continuation Error (PCE) demonstrated by pilots.

Continued flight from VFR into IMC has been labeled as a Plan Continuation Error by Orasanu, Martin, and Davison (n.d., as cited in Wiegmann, Goh, & O'Hare, 2001). A study by Burian, Orasanu, and Hitt (2000) analyzed 276 aviation incident reports that involved weather events and found that 28% of the 333 identified decision events were considered to be PCEs. This suggests that pilots may choose a course of action and stay with it regardless of the consequences or rule violations simply because they "made a plan and they were going to stick to it."

Research pertaining to weather-related decision making is abundant and what has been presented here is just a small sample from the available literature. Let us now shift to more of the general decision theories and their implications for the cockpit.

Hindsight Bias

Most people have heard of the adage "hindsight is 20/20." This implies that what we see in the past is always clearer than what can be seen now or in the future. This can create what is known as hindsight bias and this can have a profound affect on decision making. According to Plous

(1993, p.35), "Hindsight bias is the tendency to view what has already happened as relatively inevitable and obvious—without realizing that retrospective knowledge of the outcome is influencing one's judgments."

Case #1 in the beginning of this paper might be an example of hindsight bias. The pilot may have based his decision to land with an excessive tailwind because he has done this before with positive outcomes. Due to the fact that there was nothing to contradict his decisions (i.e., "I've done this a few times before and it worked out fine") the pilot will be biased into thinking that this time should be no different. The major flaw highlighted in this type of thinking is the absence of determining how things could have turned out differently (or weighing different outcomes).

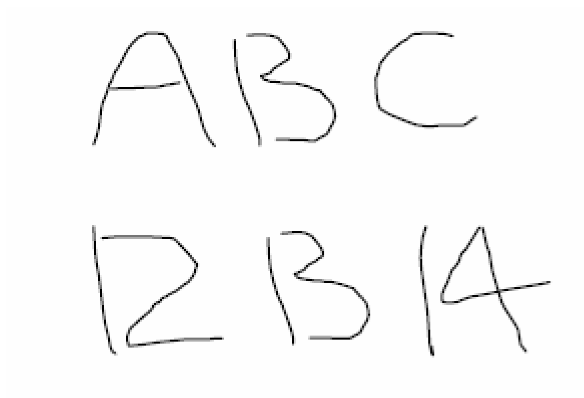
If you only consider the reasons why something turned out as it did, you run a good risk of overestimating how inevitable that outcome was and how likely similar outcomes are in the future (p.37). Recommendations for reducing hindsight bias include an awareness of its existence as well as a careful analysis of potential outcomes when making decisions.

Heuristics

A heuristic is defined as, "Usually a speculative formulation serving as a guide in the investigation or solution of a problem (Answers.com, 2005b). More specifically, heuristics can be thought of as sets of empirical rules or strategies that operate, in effect, like a rule of thumb (Solso, 2001, p.517). This topic is called heuristics (plural) because there are a few different types of heuristics commonly referred to in decision making. These include the *representative, availability,* and *congruence* heuristics. Also, the new idea of an *affect* heuristic is probably the most important development in the study of judgment heuristics in the last decades (Slovic et al., 2002, as cited in Kahneman, 2002, p.470). Although each has its own unique name, each can form a type of judgment bias in the decision making process. Because of space restraints, only the *availability* and *affect* heuristics will be discussed here.

The *availability* heuristic is based on the fact that people often judge probability by thinking of examples (Baron, 2000, p.141). The following example, as postulated by Tversky and Kahneman (1973, as cited in Baron, 2000) illustrates the point: Which is more likely, that a word in English starts with the letter K or has K as its third letter? The easiest way to try to solve this question is to think of examples of words. Most people find it easier to think of words that start with K than words with K as their third letter, so they say that the former is more probable. In fact, that is the wrong choice as the latter is more probable. This illustrates a common error that is induced by "availability" as a seemingly quick and efficient way to arrive at an answer.

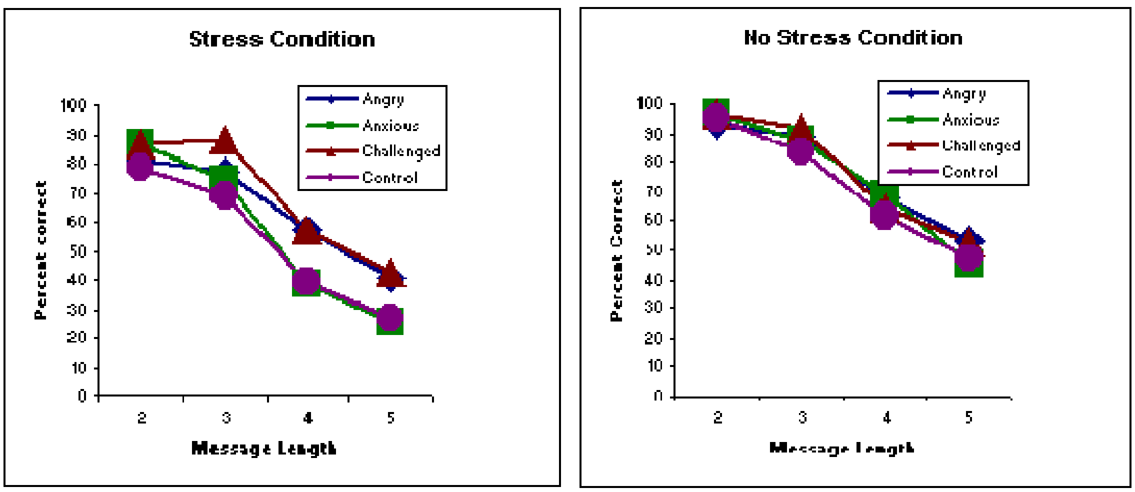
Similarly, availability can be context-dependant. We tend to think of only one meaning when presented with ambiguous stimuli, at the cost of other alternatives. Take the following for example.



(Adapted from Kahneman, 2002, p.455)

When presented with the ambiguous "13" in the row of letters, most people would think of it as the letter "B." Similarly, when the ambiguous "13" is presented in the row of numbers, most people would think of it as the number "13." While it is easy to pick up on this potential problem when the lines are presented together, this may not be the case when presented separately. In practical terms, this context dependency can affect judgment because of the possibility of ruling out other, more suitable alternatives, due to of the context of the situation.

The influence of the *affect* heuristic, as stated previously, has become more recognized and studied in recent times. According to Kahneman (2002, p.470), "There is compelling evidence for the proposition that every stimulus evokes an affective evaluation, which is not always conscious." This seems to make a lot of sense as the relationship between emotions and decisions can be inextricably linked. Emotions can be the first indication that there is a problem (i.e., "bad feeling in the gut") and can also be the first indication that a good option is recognized because it "feels right" (Barshi, 2004). Emotions can significantly affect decision skills and a series of studies have shown that when people become anxious, their ability to hold on to information in working memory is decreased. This effect appears to be limited to fear and anxiety (p.2). Two graphical representations are shown for further elucidation:



(Adapted from Barshi, 2004, p.2)

While heuristics can provide "rules of thumb" or "gut feelings," and these do provide for less processing time in non critical situations, one needs to remember that as situations become more novel or abstract there will be a higher probability of making erroneous choices. Tversky and Kahneman summed up heuristics eloquently by saying that, "Heuristics are quite useful, but sometimes they lead to severe and systematic errors." (as cited in Kahneman, 2002, p.465).

From a practical standpoint, pilots need to be aware of the limitations of heuristics when making critical decisions. When confronted with choices and alternatives requiring a course of action, remember that decisions may be influenced by heuristics that might contain flawed "operating templates" as well as affective issues that could lead to less than adequate choices.

Satisficing

Satisficing is another way that people may rationalize decisions. The term, coined by Herbert Simon (1957) with a root in economics, is a behavior which attempts to achieve at least some minimum level of a particular variable, but which does not strive to achieve its maximum possible value. Simon also posits that most people are only partly rational, and are in fact emotional or irrational in the remaining part of their actions. This is known as *bounded rationality.*

Satisficing may occur not only at the individual level, but at the collective decision making level as well. Cyert and March (1963, as cited in Reason, 1990, p.39) demonstrated that organizational planners are inclined to compromise their goal setting by choosing minimal objectives rather than those likely to yield the best possible outcome.

That being said, aviation is a skilled domain and pilots are considered experts when they apply their knowledge to decision situations (Orasanu & Martin, 1998). However, naturalistic decisions tend to be non-optimal when compared with normative mathematical models because normative approaches require time and large computational capacity to thoroughly evaluate all options, neither of which may be available to the decision maker (p.101). Humans are simply not capable of processing large amounts of information at once, so this becomes known as bounded rationality.

The implications of bounded rationality in aviation decision making can be clearly articulated when pilots face, for example, high workload or stressful situations. In these cases, the pilot might make a decision, albeit not the best decision, based strictly on a "best that can be done with so much information" mindset. The choice will more likely than not be a good one; in these cases the decision does not come under scrutiny. However, when an improper choice is made, the pilot will go back to reanalyze the choice and only then realize that there were other, more suitable choices. This typifies hindsight education, but unfortunately, some pilots may not live to learn from their bad choices.

Cognitive Dissonance

Cognitive dissonance will be the last topic relating to decision making that we will briefly look at. It should be noted that there are numerous other theories and explanations of how decisions are made. However, due to space constraints, only a few of the most well known or relevant decision theories have been included here.

Festinger (1957) postulated that pairs of cognitions can be relevant or irrelevant to one another. If two cognitions are relevant to one another, they are either consonant or dissonant. The existence of dissonance, being psychologically uncomfortable, motivates the person to reduce the dissonance and leads to avoidance of information likely to increase the dissonance. The greater the magnitude of the dissonance, the greater is the pressure to reduce it (as cited in Harmon-Jones & Mills, n.d.).

A general example of conflicting cognitions might include going to the dentist. Most people would agree that going to the dentist can be a very unpleasant experience. Yet, they also realize that going to the dentist is important to ensure healthy teeth and gums. Putting off the dentist appointment is dissonant with the potential health problems that may ensue and this causes psychological conflict. There are two ways that this dissonance can be reduced; 1) the person can try to rationalize that putting off the dentist appointment will be beneficial because of the short-term comfort of not having to hear a drill or feel pain, or 2) the person can understand that the short-term discomfort will outweigh the long-term health problems that may be associated with avoiding the dentist. If this conflict is not resolved, dissonance will continue to prevail until consonance is somehow achieved.

Conflicting cognitions are relevant in aviation decision making as well. One such example is the inappropriate (and common) descent below landing minimums in an attempt to "get there." "Get there-itis," as it has been aptly named, is a condition that pilots experience when good judgments and decisions are sacrificed because of a narrowly focused mindset. An illegal and dangerous descent below landing minimums in bad weather can certainly be viewed as a cognitive conflict. The dissonance manifests as a conflict between *arriving at your airport as planned no matter what,* and, the possible consequences that may result in your actions such as a *violation,* or worse, an *accident.* The alternatives, such as a missed approach and another attempt to land, or flying to the planned alternate airport where the weather is better, are sometimes blocked out of the pilot's thinking process even though these contingencies should have been planned for earlier.

An awareness of cognitive dissonance and its manifestations is the first step in being able to identify its effects. Like many of the other decision behaviors mentioned earlier, this awareness will hopefully help the pilot to identify yet another psychological construct that may impede the decision making process.

Conclusion

In conclusion, it is hoped that this paper has obtained its objective as a review of the literature in aviation decision making. Theoretical concepts were supported with research studies and practical examples were used for further elucidation. There are a few final comments that this author would like to add in the closing of this paper.

First, this literature review is by no means exhaustive. In fact, this review "barely scratched the surface" of the available literature on the topic. There were many fine studies that were not included here simply because of space and time constraints. However, some of the most relevant and important literature, in this author's opinion, was cited in an attempt to stimulate further interest and allow the reader to seek further information through the references provided.

Second, research results cited in this paper should be viewed with a certain level of caution. While many of the studies attempted to use valid and reliable techniques, there are still many limitations that could have affected the overall results. For example, some studies had limitations in their population sampling techniques while others used a simulator, which may have produced a "laboratory effect." Other studies simply did not have empirically-based evidence to generalize to the pilot population at large. These limitations, as well as others, should be kept in mind when drawing conclusions relating to the data.

Third, it is evident that much more research needs to be conducted in aviation decision making to better understand why pilots make erroneous decisions, and more importantly, how to implement more effective safeguards to prevent these errors from continuing to account for a disturbingly high rate of accidents.

The best advice might just be to "think before you act." Knowing some of the limitations of judgment and decision making will hopefully make you more cognizant of the pitfalls of thought.

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