[EN-049] Risk Compensation in General Aviation: The Effect of Ballistic Parachute Systems

(EIWAC 2010)

+C. Hartman*, I. Dabipi*, J. Dodoo**, J. Burrows-McElwain*

*Department of Engineering and Aviation Sciences
University of Maryland Eastern Shore
Princess Anne, Maryland, USA
chartman@umes.edu

**Department of Natural Sciences
University of Maryland Eastern Shore
Princess Anne, Maryland, USA

Abstract: In evaluating pilot's risk and decision making profiles, this paper explores the possibility that pilots may exhibit risk compensation and make riskier decisions due to the perceived additional level of safety that a ballistic parachute system provides. An available population of pilots was asked to take part in a survey that posed various flight scenarios and provided multiple-choice style "decisions". The decisions had been previously ranked by subject matter experts and assigned a risk score. Pilots responding to the online survey were assigned to one of two groups. Pilots from group one were asked to assume that they were flying a Cirrus SR-20 equipped with a ballistic parachute system. Pilots from the second group were asked to assume that they were flying a Piper Arrow. The two group's decisions were then compared. A correlational method was also employed to determine if certain demographic features, including age and total flight time, were associated with increased risk taking.

Keywords: Human Factors, Decision Making, Risk Compensation, Ballistic Parachutes

1. INTRODUCTION

Ballistic parachute systems have been promoted by their manufacturer, Ballistic Recovery Systems (BRS), and Cirrus Design Corporation, manufacturer of the Cirrus SR20 and SR22 aircraft, as safety enhancing devices. A ballistic parachute system has been included on all production Cirrus SR20 and SR22 aircraft. Installed on Cirrus aircraft, this system is known as CAPS or Cirrus Airframe Parachute System. Widely advertised as an enhancement to safety, a ballistic parachute system is designed to be deployed in an emergency situation.

After being deployed in such an emergency situation, the parachute system is designed to lower the entire aircraft to the ground at a rate that will save the occupants from serious injury. BRS has documented 199 *saves* or lives that its system has saved since its inception in the 1980s [1]. Some of the emergency situations in which these devices are meant to be deployed, as listed by Cirrus and BRS, are: mid-air collisions, pilot incapacitation, loss of control, engine failure over rough terrain, and engine failure at night.

The 2005 Nall Report, a yearly summary of General Aviation (GA) accidents published by the Aircraft Owners and Pilot's Association (AOPA), states that mid-air collisions in general aviation are "relatively" rare and that "pilot incapacitation happens very rarely" [2]. The Nall Report also indicates that failures of an aircraft or its systems are also relatively rare. So while a ballistic parachute system does provide an additional level of safety, the valid reasons for deploying such a system are rare in comparison with the most common accident types.

Much more common are accidents due to pilot-related causes or accidents due to the "improper action or inaction of the pilot", for which the Nall Report attributes 75.5 percent of all accidents and 78.6 percent of all fatal accidents [2]. Despite the additional level of safety that the CAPS system advertises, the NTSB database lists sixty-nine accidents and twenty-five fatal accidents resulting in 52 deaths in Cirrus aircraft during the period of April 2001 through February 2007 [3]. It could be argued that this was in fact due to the same common causes seen elsewhere in general aviation, most notably pilot-related causes.

One principal pilot related cause of general aviation accidents is failures in decision making. Proper decision-making is vital to safe flying. Poor decision-making by pilots has been recognized as a major factor in general aviation accidents [4]. Faulty decision making has been blamed for as many as 50 percent (50%) of all accidents [5]. A FAA study on the decision--making skills of general aviation pilots found that young pilots and pilots with a considerable amount of flight experience were more likely to make riskier decisions than older pilots or those with less experience [5].

Additionally, unnecessary risk-taking and inaccurate risk assessment can be said to contribute to a large percentage of aviation accidents. Hunter states that "poor risk assessment can contribute significantly to poor decision making" and that high levels of risk tolerance in pilots may lead them to take hazardous actions [6]. Decision-making and risk assessment play a role in each and every flight a pilot makes. This project seeks to explore the role of risk assessment as it applies specifically to flight in Cirrus Design aircraft equipped with a ballistic parachute system.

2. RISK COMPENSATION

Risk compensation is the theory that persons adapt their behavior based on their perceived risk of their surroundings. According to this theory, when humans perceive that risk or danger has increased, they will act more cautiously. Conversely, when risk is perceived to be less or a person *feels* safer, he or she will behave less cautiously. Hedlund states that "people modify their behavior in response to changes in the reward and penalty structure of their environment" [7, p. 86]. More controversial, and beyond the scope of this project, is the theory of risk homeostasis-the idea that humans will adjust their level of risk to a point that negates the benefit of mandatory safety improvements [8].

The idea that persons behave less cautiously or make riskier decisions in response to a perceived added level of safety is well documented in literature. Noland found that improvements in bicycle safety led to an increase in bicycle commuting [9]. Persons who would not have otherwise commuted by bicycle chose to commute by bicycle because of the perceived safety improvements. Conversely, Noland concluded that "increases in the perceptions of the risk of using a given transportation mode may reduce the probability of commuting by that mode." Although the findings of this study may be applicable to aviation, only walking, bicycling, and travel by auto were explored.

Assum, Bjornskau, Fosser, and Sagberg documented risk compensation in transportation when they found that drivers compensate for road lighting with both increased speed and decreased concentration. Assum et al. conclude that road lighting would have a greater "accident-reducing effect if compensation could be avoided" [10].

Another study found that children behaved in a more reckless manner when outfitted with safety equipment than they did when no safety gear was worn [11]. In a closely related study, Morronngiello, Walpole and Lanesby found that "children believed wearing safety gear made them invulnerable to any degree of injury, protected them from serious injury, and resulted in them somehow being more competent to perform a higher-risk activity" [12, p 56].

Risk compensation with respect to safety gear has been found to apply not only to children, but to their adult parents as well. Morrongiello and Major found that parents would allow their children to take significantly greater risks when equipped with safety gear than they would when the children wore no such gear [13]. These studies call for education and training that addresses the proper use of safety gear and promotes the understanding that safety gear is not a universal protection from all injury.

Haigney, Taylor and Westerman studied the effect of cellular phone use on user's behavior while driving. It was found that the perceived increased level of risk led to drivers slowing their speed during times of cell phone conversation [14]. This study provides an example of risk compensation in response to a perceived increased risk.

Schindler explored the possibility that firefighters carrying an improved fire shelter may take more risks than they would if not equipped with the new shelter. It was found that risk compensation may occur in this field due to the additional perceived level of safety; therefore mitigation of risk compensation was encouraged through targeted training [15].

3. RISK IN AVIATION

An accurate assessment of risk is critical for good decision making. Kirkbride, Jensen, Chubb and Hunter encourage pilots to create a personal minimums checklist of risk factors for assistance in preflight decision making. This process encourages pilots to consider all potential factors, from the aircraft to the environment to themselves and evaluate the risk based on all of these factors [16]. A follow-up study found that a training program to encourage pilots to create such a personal minimums checklist was well received by attendees [17].

Hunter sought to measure risk perception and risk tolerance in general aviation pilots. This study found a negative correlation between a pilot's risk perception of weather and risk tolerance in weather-related situations [6].

Therefore, the lesser the perceived weather risk, the greater weather risk a pilot would tolerate.

Green found that more than one third of the flight instructors interviewed for her study did not rate aviation as a risky activity. Green concludes that recognition of risk is an essential beginning of risk management, and that this concept should be integrated early in flight training in order to improve pilot decision making [18]. The results of a study conducted by Hunter agree with the conclusion that training in risk recognition could be highly effective in preventing accidents [6]. Molesworth, Wiggins and O'Hare concluded that pilots may gain risk assessment skills through exposure to hazardous scenarios in a simulated environment [19].

There is much literature on the topic of risk as it relates to pilots and aviation. The topics of risk assessment, risk management and risk tolerance are discussed; however, no direct connection has been made between aviation and risk compensation.

4. METHOD

4.1 Research Model

An experimental research model was used for this project. Pilots responding to the online survey were assigned to one of two groups. The group assignment was based on the question "Is your birthday on an even or odd day?". Pilots were assigned to one of the two groups depending on their answer of "odd" or "even". Pilots from group one were asked to assume that they were flying a Cirrus SR-20 equipped with a ballistic parachute system. Pilots from the second group were asked to assume that they were flying a Piper Arrow. The two group's decisions were then compared. A correlational method was also employed to determine if certain demographic features (including age and total flight time) were associated with increased risk taking.

4.2 Survey Population

The population targeted for this survey was pilots. Ninety-four (94) pilots responded to the survey, however, only 76 pilots completed the survey in its entirety. The data from the 18 pilots who did not complete the survey will be omitted from further discussion.

Of the 76 respondents, 69 (90.8%) were male, and 7 were female (9.2%). The mean age for all respondents was 42. Respondents were asked to report their pilot certifications. Forty-seven (61.8%) reported holding Private Pilot certification, while only 2 (2.6%) reported Recreational Pilot certification. There were no Sport pilot respondents. Twenty-three (30.3%) reported Commercial Pilot certification while 16 (21.1%) reported Airline Transport Pilot (ATP) certification. Sixteen (21.1%) of respondents also reported Flight Instructor certification. Forty-three (56.6%) of the respondents reported possessing an instrument rating while the remaining 33 (43.4%) indicated that they did not possess an instrument rating. Twenty-eight (36.8%) of the respondents reported possessing a multi-engine rating, while 48 (63.2%) reported no such rating.

Respondents were asked to report their total flight time by choosing one of the following groups (number of respondents, percent of total respondents): less than 100 hours (5, 6.6%), 101-250 hours (21, 27.6%), 251-500 hours (13, 17.1%), 501-1000 hours (10, 13.2%), 1001-2000 hours (6, 7.9%), 2001-5000 hours (9, 11.8%), or more than 5000 hours (12, 15.8%). The largest respondent group was 101-250 with 21 pilots (27.6). A total of 39 pilots (51.3%) reported having 500 or fewer flight hours.

Respondents were also asked to pick one or two of the following descriptions that best describes the majority of their flying: Pleasure/Personal (50, 65.8%), Business-related (22, 28.9%), Charter (1, 1.3%), Airline (7, 9.2%), Other Commercial (4, 5.3%), Military (7, 9.2%), Flight Instruction (9, 11.8%), or Training (18, 23.7%). Percentages do not equal 100% since some respondents chose more than one category to describe their flying.

4.3 Sources of Data

Data was collected through an electronic survey hosted by surveymonkey.com. In addition to responses to questionnaire items, the instrument collected demographic information on each pilot including gender, age, flight time, as well as pilot certifications and ratings.

4.4 The Data Collection Device

The questionnaire consisted of 16 scenario-type questions and two opinion questions. The scenario-type questions presented pilots with four possible responses to each scenario. Pilots were asked to choose the response that best described the action they would take in the given scenario. The scenarios used were originally developed and used in conjunction with a project completed by Driskill, et al in 1998 [5].

The opinion questions instructed pilots to rate the level to which they agreed with two separate statements using a 5-point Likert scale (Disagree Strongly = 1; Disagree Somewhat = 2; Neutral/Don't Know = 3; Agree Somewhat = 4; Strongly Agree = 5). The statements were:

1. I feel that the airplane I am flying, considering its type, condition, and equipment installed, impacts the amount of risk I am willing to accept on a given flight.

2. I feel that I may be willing to take on greater risks when flying an aircraft equipped with a ballistic parachute system than I would in an aircraft without a ballistic parachute system.

Also included in the instrument was a disclaimer and instructions for completing the questionnaire which gave information to the pilots on the aircraft they were to assume they were flying when responding to the scenarios.

4.5 Instrument Pretest

The questionnaire was used in Driskill [5]. However, some questions were eliminated and additional information was added to the instructions regarding aircraft type and equipment to be assumed in the scenarios. A pretest was conducted during the Fall semester of 2007 using a group of 12 pilots from the University of Maryland Eastern Shore to ensure clarity. This pretest used paper questionnaires. As in the study, equal numbers of pilots (6) were assigned to each of the two groups. Based on the feedback from the pretest, the number of scenarios used was reduced from 20 to 16. This was done in order to shorten the amount of time necessary to complete the survey, thereby hopefully reducing the number of surveys that would be left incomplete.

4.6 Distribution Method

The questionnaire was developed into an electronic version that was presented via surveymonkey.com. A link to the survey was sent out to pilots using the researcher’s personal contacts via email with the request to continue forwarding the link to other pilots. Pilots completed the electronic questionnaire via computer and results were tracked electronically through surveymonkey.com.

4.7 Instrument Reliability

Driskill concluded that the survey instrument used to conduct that test had adequate reliability when measured by coefficient alpha [5]. To ensure reliability in the current study, scenarios in the study were chosen to ensure that each scenario has a *match*, or a question that measures decision-making based on a similar scenario. The questionnaire was then tested for split-half reliability. Each pilot’s risk score for one half of the questions was compared to the pilot’s risk score for the other half. These scores were tested using SPSS Version 17.0 for correlation. This yielded a Pearson correlation of .503. This correlation is statistically significant at the p=0.01 level. Based on this result, some amount of instrument reliability can be assumed.

4.8 Instrument Validity

The scenarios to be used in the questionnaire were originally ranked for risk by a panel of experts in Driskill et al (1998). This ranking by subject matter experts ensures that the instrument is an accurate assessment of risk taking. In Driskill, this score was referred to as the Safety Deviation Index (SDI). However, the SDI used in the study has not been correlated with other independent measures of risk such as participation in risky activities or accident involvement. This will limit the ability to correlate the results of the study to factors such as accident involvement in the future or future risk-taking.

4.9 Procedures

In Driskill, et al, pilots were given an option of four responses to each of the scenarios. Each of the four responses to the scenarios was individually *graded* for risk by a panel of experts. Each of the responses was then assigned a risk score. A higher score in the Driskill study equated to a riskier decision. These same risk scores were used to assess the risk taking of pilots participating in the current study. Pilots received an overall risk score calculated from the sum of the risk scores of each of their decisions. This score was referred to as the Safety Deviation Index (SDI), as it was in the Driskill, et al study [5]. The mean SDI for pilots in group one, “flying” the ballistic parachute-equipped Cirrus SR-20 was compared to the mean SDI for pilots in group two, “flying” the Piper Arrow. There was a directional expectation for the SDI. It was expected that the mean SDI for group two would be lower than the mean SDI for group one.

In the current study, unlike in Driskill, et al, each pilot was also presented with two opinion questions to which they were asked to indicate their level of agreement using a five-point Likert scale.

4.10 Treatment of Data

Data was collected in Microsoft Excel format from surveymonkey.com. This data was then imported into SPSS v.17.0 for analysis. The SDI score for each pilot was calculated using SPSS based on the individual pilot’s response to each of the scenarios. Mean scores were then calculated based on categories of respondents, including group one (hereafter referred to as Cirrus Group) or group two (hereafter referred to as Piper Group) and Instrument-rated or Visual Flight Rules (VFR) only.

The null hypothesis that there was no significant difference between the mean SDI score of the Cirrus Group pilots and the mean SDI score of the Piper Group pilots was tested. A t-test was conducted to determine if the difference in the mean SDI scores was significant at the p=.05 level. A correlational method was also employed to determine if there were any significant correlations at the p=.05 level between a pilot's demographic features and a pilot's SDI.

5. RESULTS

5.1 Safety Deviation Index (SDI) Scores

The mean SDI for all pilots completing the survey was 421.31 with a Median Score of 414.62. The highest risk score was 735.15 and the lowest was 265.75, a range of 469.40. The mean SDI for the Cirrus Group was 413.88, while the mean SDI for the Piper Group was 427.31. It is important to note that this result is opposite of that which was expected.

Further analysis of the data shows a mean SDI for Instrument-rated pilots of 431.24 and a mean SDI of 408.37 for VFR-only pilots. Further breakdown shows that VFR-only pilots in the Cirrus Group had a mean SDI score of 418.23 compared to the VFR-only Piper Group's 400.15. See Table 1, right, for SDI scores broken down by category.

5.2 Analysis of SDI scores

A t-test of the mean SDI scores of the Cirrus Group as compared to the mean SDI scores of the Piper Group reveals that t = -.668. This result is not statistically significant at the p = 0.05 level with 72 degrees of freedom. Again, the directionality of these mean scores is opposite that which was expected.

A second t-test was completed to compare the mean SDI scores of VFR-only Cirrus Group and Piper Group pilots as these means matched directional expectations. The t-test yielded a t of .718, which is not statistically significant at the p = 0.05 level with 31 degrees of freedom.

5.3 Opinion Question Response

Opinion Question 1 asked pilots to rank their level of agreement with the statement "I feel that the airplane I am flying, considering its type, condition, and equipment installed, impacts the amount of risk I am willing to accept on a given flight." Overall, pilots agreed, however slightly, with this statement, giving a mean response of 3.58. VFR-only pilots were slightly less likely to agree (3.36) while Instrument-rated pilots indicated slightly stronger agreement (3.74).

		Mean SDI	N	Std. Deviation
VFR-only pilots	Cirrus Group	418.2327	15	79.13213
	Piper Group	400.1483	18	65.67336
	Total	408.3685	33	71.51555
Instrument-rated pilots	Cirrus Group	410.4479	19	92.79381
	Piper Group	447.6967	24	98.50094
	Total	431.2379	43	96.71535
Total (All respondents)	Cirrus Group	413.8824	34	85.84110
	Piper Group	427.3188	42	88.30812
	Total	421.3078	76	86.89384

Table 1 Instrument rated versus VFR-only pilot's SDI scores

Opinion Question 2 asked pilots to rate their level of agreement with the following statement "I feel that I may be willing to take on greater risks when flying an aircraft equipped with a ballistic parachute system than I would in an aircraft without a ballistic parachute system." Pilots disagreed with this statement, giving a mean response of 1.68. VFR-only pilots disagreed less strongly (1.97), while Instrument-rated pilots disagreed somewhat more strongly. Of all pilots, VFR-only Cirrus Group pilots responded with the least disagreement with a mean of 2.13.

5.4 Correlations

A Pearson Correlation analysis was performed in order to determine if any correlations existed between key demographic features and SDI or responses to opinion questions. As seen in Table 2, below, significant statistical correlations exist between pilot's responses to Opinion question 2 and the pilot's age as well as his or her total flight time.

	Age	Cirrus or Piper Group	Total flight time
SDI	-.177	.077	.103
Opinion Question 1	-.099	-.026	.163
Opinion Question 2	-.227*	-.068	-.241*

Table 2 Correlations with Demographic Data

* Correlation is significant at the 0.05 level (2-tailed)

In these cases an inverse relationship exists between the age and total flight time of a pilot and the pilot's level of agreement with Opinion Question 2. No such significant correlations exist between these demographic features and a pilot's SDI or responses to Opinion Question 1.

6. DISCUSSION

6.1 SDI Scores

Although statistically significant differences did not exist between the SDI scores of pilots in the Cirrus group as compared to pilots in the Piper group, some interesting observations can still be made. First, it is important to understand that the survey, as originally designed, was intended for VFR-pilots only. In this project, the researcher was unable to achieve a substantial sample size of VFR-only pilots. Since the sample was chosen from available sources, a mix of VFR and Instrument-rated pilots resulted. Since the scenarios in this survey were originally written with VFR-only pilots in mind, they did not present options that Instrument-rated pilots would be likely to use. For example, several Instrument-rated pilots commented that they would have filed and proceeded under Instrument Flight Rules given the situation presented to them in the scenario. That option was not available, however.

In light of this, it is interesting to observe the SDI scores of just VFR-only pilots. This further diminishes the sample size to only 33 pilots (See Table 1, page 21). VFR-only pilots in the Cirrus Group had a mean SDI of 418.2, while VFR-only Piper pilots had a mean SDI of 400.1. This result lines up with initial expectations that Cirrus pilots would have higher SDI scores, and therefore make riskier decisions, than Piper pilots. This result, however, was not statistically significant, given the small sample size. This small sample size also inhibits the ability to generalize this result to the pilot population as a whole.

Also interesting to note is that pilots with the greatest flight time, those reporting more than 5,000 hours, have the highest overall SDI score with a mean of 455.2 (Table 2). This may be due to the fact that pilots with greater levels of experience feel at greater ease with a wider variety of situations than do pilots with less flight time, and therefore fewer experiences.

6.2 Correlations

Several significant correlations are of interest in this study. First, the negative correlation (-.227) between a pilots age and his/her response to opinion question 2 indicated that the older a pilot is, the more strongly they disagree with the idea that they may take on greater risks in a ballistic-parachute equipped aircraft. Similarly, a negative correlation (-.241) existed between a pilot's total flight time and his or her answer to opinion question 2. These results seemed to signify that the older and the more experienced a pilot is, the less likely they are to agree that they may take on additional risks in response to additional safety equipment.

This result has several possible explanations. First, pilots, as they get older and gain experience, may simply be unwilling to accept certain risks, regardless of the aircraft equipment. The second possible explanation of this result is that older and more experienced pilots are simply less willing to admit that they may take on greater risks in ballistic-parachute equipped aircraft. Both explanations have ramifications for the design of future training programs.

7. CONCLUSIONS

It has been demonstrated in the past that individual pilots are willing to accept varying levels of risk and may even be unaware of the risk they are undertaking. The effect of risk compensation has been well documented in fields other that aviation and it has been demonstrated that humans do in fact alter their behavior in response to perceived safety. Simply put, humans tend to behave more recklessly when they feel safer. Given these points, it is highly probable that some sort of risk compensation may play a part in the decision making of general aviation pilots.

A ballistic parachute system is one of many safety enhancements that may potentially lead pilots to take greater risks. Weather radar, moving map GPS, radar altimeters, TCAS (Traffic Avoidance and Collision Systems), among others may all serve to make pilots "feel" safer with respect to their current situation. These devices certainly enhance safety and their value in this regard is not being questioned. However, the possibility that these devices lead to a level of complacency or a greater willingness to accept risks must be further explored.

Although a multitude of proven safety enhancements are employed on Cirrus Design Corp. SR-20 and SR-22 aircraft, fatal accidents continue to occur. In spite of the fact that the final cause of many of the most recent accidents is still unknown, several have been attributed to faulty pilot decision making and risk-taking. One such accident occurred on January 13, 2006, when a pilot decided to fly into known icing conditions for which the aircraft was not equipped. All aboard were saved when the ballistic parachute was deployed [20].

Exploring the possibility of risk compensation in this example involves asking a simple question. That question is: would the accident pilot have made the decision to continue flight into icing conditions had his aircraft not been equipped with a ballistic parachute system and other safety devices? If the answer is no, then risk compensation did play a part in this accident. The pilot made riskier decisions as a result of a perceived increased level of safety provided by the safety devices installed on the aircraft. Unfortunately, only the failures in decision making can be examined when it comes to accidents. The reasons for the decisions can only be speculated. The accident pilot may have made the same poor decisions regardless of equipment.

The TAA safety study team found that although Technically Advanced Aircraft (TAA) provide a potential for increased safety, this safety can only be achieved through additional training so that pilots learn to operate within the limitations of those systems. The TAA safety study team goes on to state that "the traditional GA training system… does not include training on how to make accurate flight risk assessments and manage flight risk properly" [21].

This research, although limited in sample size, does demonstrate that pilots may, in fact, take on greater risks in an aircraft equipped with a ballistic parachute system. This trait in pilots may in fact vary with their level of experience and/or age. It is also interesting to note that younger, less experienced pilots seem to be more willing to admit that they would take on these additional risks in a ballistic-parachute equipped aircraft. These findings make it clear that additional research is necessary in order to better understand the decision-making process of pilots.

7.1 Recommendations

Research has always attempted to discover the root causes of aviation accidents so they can be avoided in the future. A thorough understanding of the causes of accidents leads to improvements in training and design. Much of the design of Cirrus aircraft is owed to an attempt to design a system that protects pilots and passengers from injury. Since so many aviation accidents can be attributed to faulty pilot decision making, it is vital that further research attempts to understand how pilots think. This research should further explore, with a greater sample size than the current project, the possibility that pilots make riskier decisions when equipped with "safer" equipment. Should this prove to be true, additional training should be developed, and methodically tested to ensure that it effectively combats this issue.

8. ACKNOWLEDGEMENTS

The author completed this paper in fulfillment of the Graduate Capstone Project while pursuing a Master's of Aeronautical Science Degree from Embry Riddle Aeronautical University. Special thanks to Dr. Roxanna Austin and Mr. Terry Cobb.

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10. COPYRIGHT

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