THE EFFECT OF UPSET RECOVERY TRAINING ON THE INITIAL PILOT REACTION DURING AN INADVERTENT UPSET SITUATION

by

Trevor Devaughn Bourne Jr.

A Graduate Capstone Project Submitted to the College of Aviation,
Department of Graduate Studies, in Partial Fulfillment
of the Requirements for the Degree of
Master of Science in Aeronautics

Embry-Riddle Aeronautical University
Daytona Beach, Florida
August, 2016

THE EFFECT OF UPSET RECOVERY TRAINING ON THE INITIAL PILOT REACTION DURING AN INADVERTENT UPSET SITUATION

by

Trevor Devaughn Bourne Jr.

This Graduate Capstone Project was prepared under the direction of the candidate's Graduate Capstone Project Chair, Dr. Andrew. R. Dattel, Professor, Daytona Beach Campus, and has been approved. It was submitted to the Department of Graduate Studies in partial fulfillment of the requirements for the degree of Master of Science in Aeronautics

Graduate Capstone Project:

____
Andrew. Dattel, Ph.D.
Graduate Capstone Project Chair

____
Donald. Metscher, Ph.D.
Program Coordinator
Master of Science in Aeronautics

____
Date

Acknowledgements

I would like to thank all the individuals who assisted me in the completion of this project. Specifically I would like to thank the following:

I would like to thank Dr. Andrew Dattel my Graduate Capstone Project Chair for his guidance and help through this project. I would also like to thank Dr. Kenneth Byrnes and Mr. Raul Rambaut for granting me permission to use the University's flight simulators to conduct this research study. I would like to thank Mr. Alain Aguayo for taking the time out to evaluate the simulators performance in upset situations. Lastly, I would like to thank Ms. Amber Davis for her assistance in improving my writing skills. Without the help of the individuals stated above this study would have been impossible to complete.

Abstract

Scholar: Trevor Devaughn Bourne Jr.

Title: The Effect of Upset Recovery Training on the Initial Pilot Reaction during An Inadvertent Upset Situation

Institution: Embry-Riddle Aeronautical University

Degree: Master of Science in Aeronautics

Year: 2016

Across the aviation industry, loss of control in flight remains the number one cause for fatal accidents, with only 30% of those accidents being the result of a system or component malfunction (Belcastro & Foster, 2010). Most loss of control mishaps result from pilots making the incorrect inputs on the controls — if inputs are even made on the controls. This research will investigate the initial inputs of pilots in upset situations.

Two groups of 18 participants each were selected based on if they have had upset recovery training or not. This research was a quasi-experimental research design. The independent variable within the study will be Upset Recovery Experience, with 2 levels: participants who have taken an upset recovery training class and participants who have not taken an upset recovery training class. The dependent variables will be: Altitude Loss, Reaction Times, G-Loading, Time to Recover and Initial Control Input. It was found that the Altitude Loss of pilots that had received upset recovery training was significantly lower than pilots who had not have upset recovery training; the Initial Reaction Time of pilots that had received upset recovery training was significantly lower than pilots who have not had upset recovery training; and that pilots who had upset recovery training reacted correctly (pushed or rolled) whereas pilot without upset recovery training reacted incorrectly (pulled). No differences were found in the Maximum G-Load and the Time to Recovery from the aircraft inverted scenario. Based on these findings, the researcher recommends to the FAA to consider incorporating upset recover training into pilot training, certification and flight reviews.

Table of Contents

List of Tables

List of Figures

.

Chapter I

Introduction

A number of fatal accidents attributed to human error result from inadvertent upset situations (Belcastro & Foster, 2010). Although the Federal Aviation Administration (FAA) requires recovery training from unusual attitudes as a part of pilot certification, it is limited in scope. The FAA's requirements for pilot certification does not account for aircraft upsets including situations that involve aircraft attitudes outside of the descending V_{NE}, and climbing stall condition.

This study focused on discovering the initial reaction as well as the recovery techniques of pilots when in an inadvertent upset situation based on if the pilot has received upset recovery training or not. It would seem that a lot of fatal accidents are caused by improper recovery techniques. The intention of the study was to find out if upset recovery training can help to reduce fatal accidents by teaching proper recovery techniques. The researcher used a Frasca Level 6 Flight Training Device (FTD), which simulated flying conditions; the researcher assigned a scenario to the participant, and then extracted the data from the FTD to be analyzed. For the purpose of this research, an upset situation is any airplane attitude in which the bank exceeds 45 degrees and pitch is in excess of 30 degrees up and 20 degrees down. Upset recovery for the purpose of this study is defined as the techniques used to recover from any aircraft upset situation.

Significance of the Study

The significance of this study is to see if there are ways to reduce accidents attributed to human error in upset situations**.** This study would benefit the FAA as well as the National Transportation Safety Board (NTSB) by making recommendations for the NTSB for the FAA.

The recommendations will be intended to provide input to the FAA about incorporating upset recovery training within flight certification training and recurrent training that could reduce the number of fatal accident caused by aircraft upsets. This study will add to the body of existing research by adding findings on the initial physical reactions and reactions times in inadvertent upset situation.

Statement of the Problem

Commercial aviation today is considered one of the safest methods of transportation (Stolzer & Halford, 2004). However, loss of control in flight (LOC-I) still remains the number one cause of fatal accidents in the aviation industry across the world. Less than 31% of LOC-I accidents are a result of system or equipment malfunction (Belcastro & Foster, 2010). This means that the remaining 69% of LOC-I accidents may be due to, but not limited to, the pilot's reaction to inadvertent upset situations. Too many lives are being lost in such fatal accidents and this problem must be addressed. Identifying if upset recovery training experience has an effect on pilot reactions and recovery technique can possibly lead to the development of courses to prevent accidents of this nature reducing the number of LOC-I accidents.

Purpose Statement

The purpose of this study is to evaluate if upset recovery training has a positive impact on reducing accidents by using a simulator, differences in the reaction time, altitude loss, g-loading, time to recover and initial physical input on the controls, when recovering from upset situations based on if the pilot has received upset recovery training or not.

Hypotheses

The following null hypotheses were tested.

H1: There is no difference in the physical initial reaction time of pilots based on having upset recovery training or not having upset recovery training when inadvertently placed in upset situations.

H2: There is no difference in the maximum g-load pulled based on having upset recovery training or not having upset recovery training when inadvertently placed in upset situations.

H3: There is no difference in the altitude loss based on having upset recovery training or not having upset recovery training when inadvertently placed in upset situations

H4: There is no difference in the recovery time from the aircraft upset based on having upset recovery training or not having upset recovery training when inadvertently placed in upset situations.

H5: There is no difference in the initial physical reaction of pilots based on having upset recovery training or not having upset recovery training when inadvertently placed in upset situations.

Delimitations

For the purposes of this study, the only pilots that are eligible to participate in this study are pilots holding a commercial pilot or higher, and or having in excess of 250 flight hours, and having at least 10 hours flown within the past 30 days. The reason for this delimitation is that a private pilot with under 250 hours is relatively inexperienced and may not be able to fly an airplane competently without putting a lot of effort into it. Therefore, if a private pilot with under 250 hours is placed into an upset situation their reactions may be unfit to represent the general population of pilots due to low experience. To prevent the data from being inaccurate based on lack of aeronautical experience, and in an effort to better generalize the effect of upset recovery on the population of pilots, private pilots whom had under 250 hours were not allowed to participate in this study.

Limitations and Assumptions

Due to the nature of this study, multiple limitations exist. Participants that were used in this study were active pilots at Embry-Riddle Aeronautical University (ERAU). The usage of only ERAU participants was due to the researcher not having the ability to recruit pilots outside of ERAU to fly the institution's FTDs.

Due to the risks associated with putting participants into an actual airplane for upset situations, a FTD was utilized. The Frasca 172 FTD performance in upset situations is not guaranteed to replicate the actual performance of the Cessna 172 (C-172) aircraft. Therefore, the data obtained may not necessarily match the same data one would get if this experiment was carried out in the C-172; however, the data collected does not need to replicate the actual airplanes performance the data only needs to be reliable and using the same FTD device will provide reliable data.

List of Acronyms

AFSC	Advanced flight simulation center
DAB	Daytona Beach international airport
ERAU	Embry-Riddle Aeronautical University
FTD	Flight training device
FAA	Federal Aviation Administration
GPS	Global positioning system
IMC	Instrument meteorological conditions
LOC-I	Loss of control in flight

MLB	Melbourne international airport
NSTB	National Transportation Safety Board

Chapter II

Review of the Relevant Literature

Whenever pilots get into any sort of adverse situation when flying, they will make a decision (hopefully) on what to do given the conditions experienced. In the aviation industry this is called aviation decision making.

Aviation decision making (ADM), which is defined by the FAA as “a systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances. It is what a pilot intends to do based on the latest information he or she has in any given situation” (Federal Aviation Administration, 2008, p. 386). ADM is a concept that can be taught to pilots at the rote and maybe the understanding level. However, pilots may not know how to effectively apply the rote knowledge to a given set of circumstances until they are exposed to these unusual scenarios, such as upset situations.

The Commercial Aviation Safety Team and the Joint Safety Analysis Team defines loss of control as “unintended departure of the aircraft from controlled flight, the operational flight envelope, or unusual flight attitudes, including ground events” (Commercial Aviation Safety Team, 2000, p. 12). Research about upset recovery training that aids in the prevention of loss of control has been carried out in respect to integrating upset recovery training courses in collegiate flight training programs (Rogers, 2003). Research concerning fatal accidents caused by pilot error in upset situations and requirements for mandatory upset recovery training was also conducted (Dillman, & Stanley, 2003); however no research was found to cover the initial reaction of pilots when inadvertently placed in upset situations based on if the pilot had received upset recovery training or not. LOC-I due to flight crew errors may be due to manual handling/flight controls, which could account for 29% of these accidents (International Air Transportation Association, 2015).

Visual Flight Conditions into Instrument Meteorological Conditions

Research has shown that there is a significant relationship between non-rated instrument pilots flying into instrument meteorological conditions (IMC) and fatal accidents (Ison, 2014). Wiegmann and Goh (2002) claim that pilots on cross county flights become disoriented and fly into IMC. Accidents of this nature may typically occur as a result of LOC-I from lack of proper upset recovery techniques resulting in controlled flight into terrain. The FAA mandates recovery from unusual attitudes training for private pilots under simulated conditions. However, these conditions, per the FAA practical test standards, only require applicants to be evaluated in a climbing stall attitude and a descending never exceed pitch attitude. Therefore, this standard does not account for operations outside of that flight envelope (Federal Aviation Administration, 2002). If upset recovery training is taught, it should improve pilot performance when inadvertently in upset situations to cover attitudes beyond the FAA's two requirements which are the stalling and the descending never exceed speed condition. In this case, the pilot will most likely choose the correct initial reactions to recover based on his/her training on upset recovery, reducing the number of fatalities.

Highly Perishable Skill

To prevent the skillset of upset recovery techniques from being perished, the FAA should incorporate upset recovery training into biannual flight reviews. Research carried out about the practice of upset recovery techniques explained that although upset recovery training is very useful and initially effective, over time, the skill set becomes highly perishable (Kochan, Breiter,

& Hilscher, 2005). Highly perishable means that if not practiced upset recovery skills can be lost, or forgotten. Even though upset recovery training has been shown to improve pilot performance in upset situations, if this skill is not practiced it will not benefit the pilots (Kochan et al., 2005).

Mental Practice and Performance

If a pilot receives upset recovery training in the form of oral, flight, or simulator training, it should help the pilot to work through a thought process and continue to process each upset situation by mentally practicing them. Mental practice of upset recovery has had a significant positive effect on performance (Driskell, Cooper, & Moran, 1994). If upset recovery training is introduced to pilots, it will allow them to work through a mental process that will yield favorable initial reactions. Favorable initial reactions are actions that will result in the fastest and safest recovery from the upset situation.

Simulator Based Training on Upset Recovery

Rogers, Boquet, Howell, & DeJohn, (2010), compared two groups of pilots in upset situations. One group of pilots was given low cost training via flight simulator software and another group was given no training. The participants were then placed into real aerobatic planes and were asked to recover. It was suggested that simulator-based training combined with classroom instruction improves a pilot's ability to recover an airplane from an upset (Rogers et al., 2010). It would seem that pilots with upset recovery training will demonstrate improved performance, making the correct reactions in upset situations and pilots without upset recovery training will demonstrate reduced performance in upset situations. Even though prior research states that having upset recovery training should have an effect on the pilot's ability to recover from an upset, no research has been undertaken that speaks to the initial reaction of pilot in upset situations (Rogers et al.,2010). In upset situations, the initial reaction will often determine the outcome.

Loss of Control and Commercial Jets

As mentioned earlier, loss of control in flight remains the number one cause for fatal accidents in aviation. According to Boeing, LOC-I accounted for 17 out of the 72 fatal commercial jet aviation accidents worldwide between the years of 2005 and 2014. Yielding a total of 1,706 fatalities including external fatalities as shown in Figure 1 (Boeing Commercial Airplanes Group, 2014)

Figure 1.

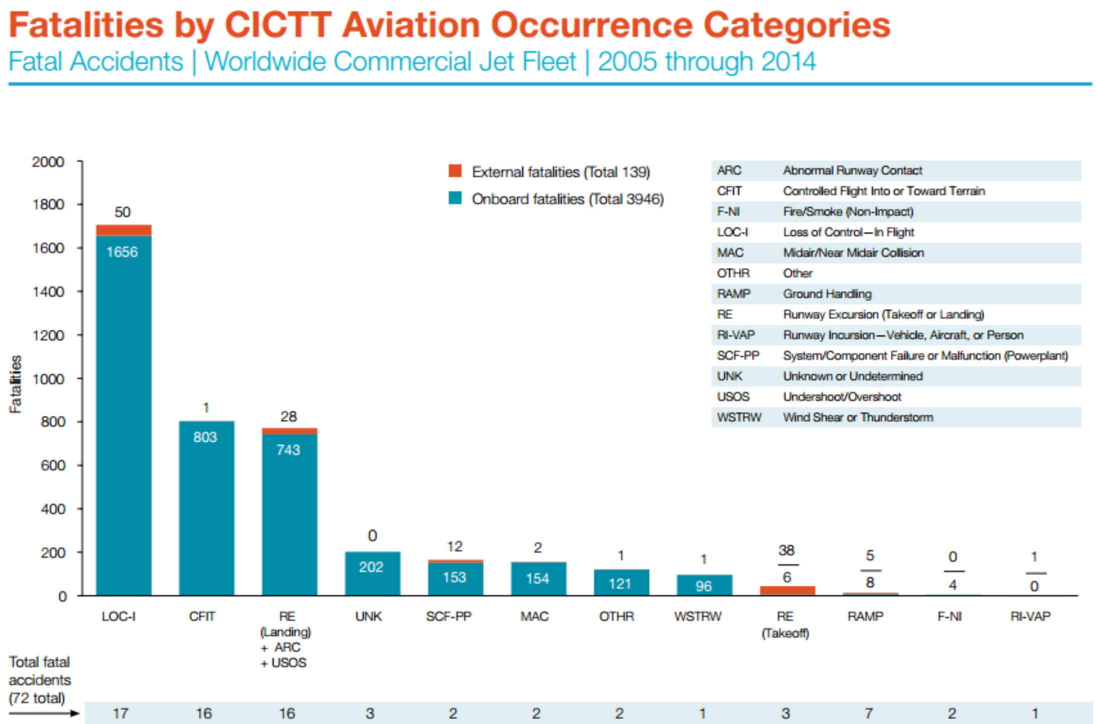


Figure 1. Displaying fatalities by CICTT Aviation Occurrence Categories between the years of 2005-2014. Adapted from Boeing Commercial Airplanes Group (2014). Statistical summary of commercial jet airplane accidents: Worldwide operations 1959 – 2014. Seattle WA: Airplane Safety.

Boeing's data, however, only accounts for commercial jet aviation and does not include corporate and general aviation, where most of the fatalities occur in aviation. Commercial airliners typically provide their pilots with upset recovery training within the US. However, this may not be the case in foreign countries.

Practice Effects on Reaction Time

Ando, Kida, and Oda (2002), state that there is a decrease in reaction time with practice. The findings support the theory that having upset recovery training will lead to a reduced reaction time. The research conducted by Ando et al., 2002, investigated the reaction time for the participant to press a key based on a visual stimulus whereas this study on upset recovery reaction times investigates the reaction time to initiate a recovery to the aircraft upset.

Inverted Recoveries

Altitude loss in inverted recoveries can be minimized by using proper recovery techniques. These techniques are different, depending on the attitude of the airplane at the time recovery is initially executed Recoveries from inverted flight should be accomplished first by adding forward pressure on the controls to raise the nose towards the horizon after which the airplane should be rolled towards the nearest horizon (Crawford, 2009). Executing the recovery as recommended should result in the lowest altitude loss,

Summary

The literature relevant to this study has illustrated that many research studies have been conducted on upset recovery. In past studies it was found that receiving upset recovery training improved pilot performance; however, studies concerning the initial reaction of pilots in inadvertent upset situations was scarce. Many loss of control accidents as a result of improper upset recovery techniques were observed in IMC flight. However, FAA's certification standards do not require applicants to be evaluated on recovering from upset situations outside of the normal flight envelope. Because of the perishability of skills theory, if upset recovery techniques are not practiced, then the skillset may decay. Upset recovery techniques, if practiced, not only keep the skillset intact but also gives the pilot the opportunity to work through a thought process by mentally practicing these techniques, which will improve reaction times as well as the quality of the reaction. To better evaluate the initial physical reactions of pilots in this study the guidelines from Crawford, (2009) will be used. The recovery procedure for inverted flight as stated by Crawford is to push and then roll the airplane towards the closest horizon (Crawford, 2009).

Chapter III

Methodology

Research Approach

The research approach was quasi-experimental and had quantitative data. The independent variable in the study was Experience, and the levels of this independent viable are Upset Recovery Experience and No Upset Recovery experience. The dependent variables were altitude loss, reaction times, g-loading, initial reactions, and time to recover.

Design and procedures. The researcher recruited participants and placed them through the Inverted In-Trail Scenario. A total of 36 participants were selected. Each participant in the upset recovery experience group was assigned an odd participant ID number each participant in the no upset recovery experience group was assigned an even participant ID number. This research design was a one way quasi-experimental design.

Table 1

Experimental Design

Scenario	Experience Level	
	Upset Recovery	No Upset Recovery
1	Participant ID#3 (d,e,f,g,h)	Participant ID#2 (d,e,f,g,h)

Note. d = altitude loss, e = g-load, f = reaction time, g= initial reaction, h= time to recover

Apparatus and materials. For this experiment, the Frasca Level 6 C172 FTD was used to simulate flying conditions and upset situations. Using the F172 FTD enhanced the mundane and experimental realism of the experiment. The FTD device is capable of recording multiple flight parameters, which the researcher retrieved after the experiment was completed. Each participant's reaction time to the upset situation was extracted from the F172 output file and exported to an Excel file in a comma separated value format. Each participant was evaluated based on the scenario listed below. This scenario was programmed by the researcher before the participants arrived. The total duration of the entire experiment was approximately 10 minutes. The scenario is explained below.

Scenario. The participant was briefed that they are on an instrument flight plan flying director to the Melbourne International airport. The scenario is currently at paused 6,000 feet, once the participant is situated in the cockpit they were instructed to give the researcher the go ahead to un-pause the simulator. The FTD was then be un-paused and the recorder was started. After flying straight and level on a direct course to the Melbourne International Airport, the researcher announced "riddle 877 use caution there is an Airbus A380 flying overhead same direction at 7000 feet." After 30 seconds following the initial ATC contact the researcher announced "riddle 877 I have lost radar contact with you, squawk 1002 IDENT." Immediately after the participant pressed the IDENT button the aircraft was placed in an inverted attitude simulating getting caught into the A380's wake.

The data analyzed started from where the plane was flipped inverted and the analysis stopped when the pilot has recovered. Recovered, for the purpose of this study is when the aircraft is established in a positive climb and then bank is within $\pm$ 5 degrees of straight (no bank) flight.

Sample

There were several methods used to recruit participants for this study. The first method was recruiting participants verbally on the ERAU campus. The second method of recruiting participants was accomplished by sending a message through the ETA Flight Training Software to all active pilots at ERAU. For the propose of this study, an active pilot was any pilot who has flown more than 10 hours in the past 30 days.

Participant selection was based on the following process. The first thing the researcher did was to determine if the participant held a commercial pilot certificate or higher or more than 250 flight hours. If the participant did not possess a commercial pilot certificate or higher or more than 250 flight hours, he or she was not permitted to participate in the study. The second thing the researcher did was to determine if the participant has received upset recovery training or not, which determined what level of the independent variable the participant was placed in. Upset recovery training for the purpose of this study was any participant that has completed FA215 at ERAU, or who has over 20 hours of upset recovery training in an aerobatic airplane. The two levels of the independent variable are: (a) upset recovery experience, and (b) no upset recovery experience. A total of 36 participants were selected.

Data Collection Device

The data collected came from the Frasca 172 simulator data recorder. The variables extracted from the Frasca 172 simulator for analysis were Altitude, G-Load, Time, Bank Angle and Vertical Speed. The researcher visually observed the participants and recorded their initial physical reaction on the controls when placed into the upset situation. The initial reaction time was calculated by finding the difference between the time the aircraft was flipped inverted and the time the researcher flagged the reaction on the controls, these time stamps were flagged in the data output file. The reason the researcher had to make this observation was due to the lack of the FTDs ability to capture control inputs.

Treatment of the Data

Five independent samples t-test were run. The first *t*-test was run to determine weather or not there was a significant difference in Altitude Loss. The second *t*-test was run to determine if there was a significant difference in Reaction Time. The third *t*-test was run to determine if there was a significant difference in maximum G-Load. The fourth *t*-test was run to determine if there was a significant difference in the Time to Recovery from the upset situation. The fifth *t*-test was run to determine weather or not there was a significant difference in Altitude Loss based on if the pilot pulled or rolled/pushed initially during the recovery.

A chi square test of independence was done to compare the difference in reactions based on whether or not the pilot had received upset recovery training.

The altitude loss was determined from the simulators output file. This was accomplished by finding the difference between the altitude that the airplane rolled inverted (identified by the drastic change in bank angle from level flight to approximately -177 degrees) and the altitude that the participant achieved a positive rate of climb with a bank angle of $\pm$5 degrees of straight (wings level). This was all determined by analyzing the output files.

The vertical g-force for the entire scenario flown was recorded by the simulator and recorded in the simulators output file. The researcher used an excel formula (=max(cell range)) to determine the maximum g- load. The greatest g-load recorded in this experiment was 3.67 G.

The physical initial reaction was determined by the researcher's observations of the participants. Once the participant pressed the IDENT button and the airplane was rolled inverted the researcher observed the participant's initial control input and recorded it. The researcher also flagged the time at which they reacted in the output file to determine the reaction time by making a bookmark (clicking the bookmark icon). This was done by finding the difference in the time stamps between when the airplane was rolled inverted (identified by drastic change in bank angle from level flight to approximately -177 degrees) and when the bookmark was observed in the output file.

The recovery time was determined from the simulators output file. This was accomplished by finding the difference between the time stamp from when the airplane rolled inverted (identified by the drastic change in bank angle from level flight to approximately -177 degrees) and the time stamp when the participant achieved a positive rate of climb with a bank angle of ±5 degrees of straight (wings level). This was all determined by analyzing the output files.

Chapter IV

Results

The following results were based on the data obtained from the Frasca 172 Simulator output file and the researcher's observations. The descriptive statistics of the variables analyzed are presented below. In addition to the descriptive statistics, the analysis for each individual hypothesis will be presented in this section.

Descriptive Statistics.

The dependent variables for the study were Altitude Loss, Maximum G-Load, Reaction Time, and Time to Recover. Table below 2 shows the descriptive statistics for the pilots who had upset recovery training and pilot who did not have upset recovery training.

Table 2

Descriptive Statistics for pilots who had upset recovery training and pilots who did not have upset recovery training.

Variables	Group	N	Minimum	Maximum	Mean	Standard Deviation
Altitude Loss (Feet)	Upset Experience	18	726	3032.03	1674.07	747.99
	No Upset Experience	18	1044	3986.04	2365.41	779.79
Maximum G-Load (G's)	Upset Experience	18	1.57	3.67	2.68	0.619
	No Upset Experience	18	1.72	3.5	2.72	0.47
Reaction Time (Seconds)	Upset Experience	18	0.8	2.2	1.41	0.35
	No Upset Experience	18	0.7	3.2	1.83	0.74
Time to Recover (Seconds)	Upset Experience	18	5.4	24.4	12.97	4.83
	No Upset Experience	18	9.2	30	15.52	4.72

Altitude loss.

The first null hypothesis was there is no difference in the altitude loss based on having upset recovery training or not having upset recovery training when inadvertently placed in upset situations. An independent samples *t*-test was run for this hypothesis. All four assumptions normality, random sampling, independence and equal variances were met. The independent samples *t*- test showed that the altitude loss for pilots that had received upset recovery training was significantly lower than pilots who did not receive upset recovery training, $t(34) = -2.678$, $p = .011$ (see Figure 2); therefore, this null hypothesis was rejected.

Figure 2.

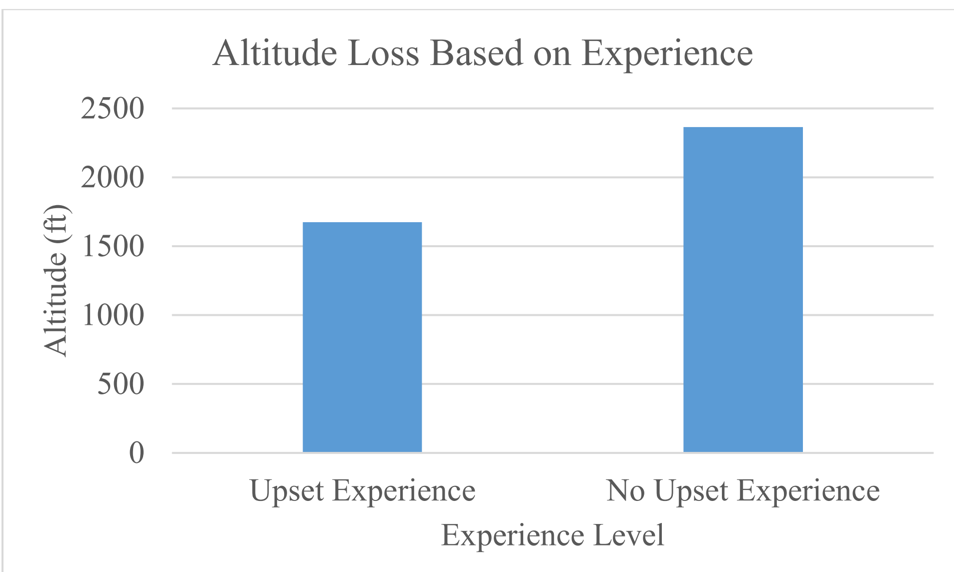


Figure 2. Showing the mean altitude loss during recovery from the aircraft upset for pilots whom had upset recovery training and pilots who did not have upset recovery training.

Reaction time.

The second null hypothesis was there is no difference in the physical initial reaction times of pilots based on having upset recovery training or not having upset recovery training when inadvertently placed in upset situations. An independent samples *t*-test was run for this hypothesis using the data from the FTD flight data recorder. All the four assumptions normality, random sampling, independence and equal variances were checked; however there was a violation in the homogeneity of variances Levene's statistic $p < .05$ and the degrees of freedom was adjusted. The independent samples *t*-test showed that the initial physical reaction time for pilots that had received upset recovery training was significantly faster than pilots who did not receive upset recovery training $t(24.318) = -2.180$, $p = .039$ (see Figure 3). Therefore, the null hypothesis was rejected.

Figure 3.

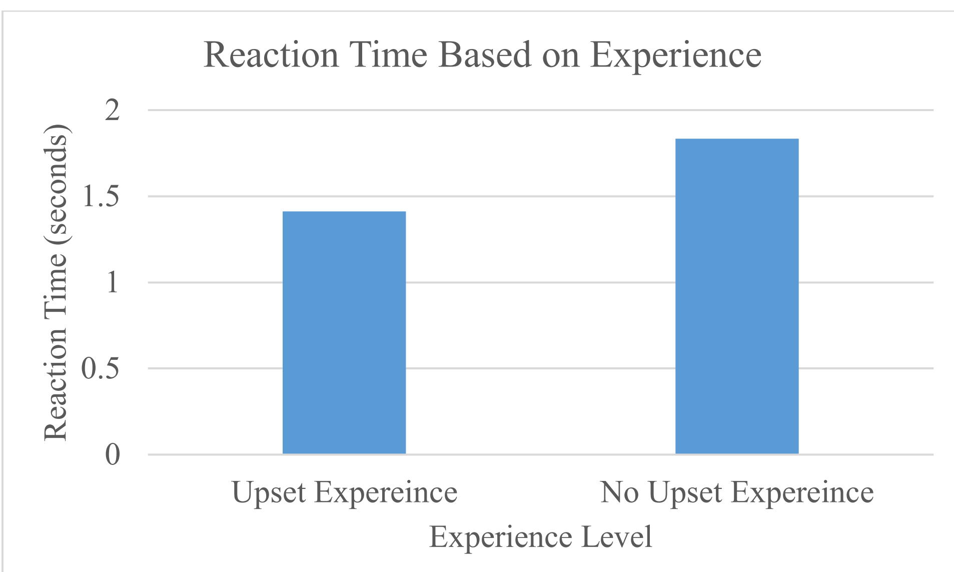


Figure 3. Showing the mean initial physical reaction times for pilots who had upset recovery training and pilots who did not have upset recovery training.

Vertical g-force.

The third null hypothesis was there is no difference in the maximum g-load of pilots based on having upset recovery training or not having upset recovery training when inadvertently placed in upset situations. An independent samples *t*-test was run for this hypothesis using the data from the FTD flight data recorder. All the four assumptions normality, random sampling, independence and equal variances were met. The independent samples *t*-test showed that the maximum g-load for pilots that had received upset recovery training was not significantly different from pilots who did not receive upset recovery training, $t(34) = -2.40$, $p = .812$. Therefore, the null hypothesis was retained.

Time to recover.

The fourth null hypothesis was there is no difference in the recovery time from the aircraft upset based on having upset recovery training or not having upset recovery training when inadvertently placed in upset situations. An independent samples *t*- test was ran for this hypothesis using the data from the FTD flight data recorder. All the four assumptions normality, random sampling, independence and equal variances, were met. The independent samples *t*-test showed that the time to recover from the aircraft upset for pilots that had received upset recovery training was not significantly different from pilots who did not receive upset recovery training, $t(34) = -1.600$, $p = .119$. Therefore the null hypothesis was retained.

Altitude Loss Based on Initial Reaction

The fifth independent sample *t*-test was conducted to determine if there was a significant difference in the altitude loss during recovery from the inverted scenario based on if the pilot pulled initially or rolled/pushed initially on the control yolk. The independent samples *t*- test showed that the altitude loss for pilots who pulled (M = 2769.032, SD = 498.768) initially was significantly higher than if the pilot pushed or rolled (M = 1596.238, SD = 683.519), $t(34)$ = 5.411, $p < .001$ (see Figure 4).

Figure 4.

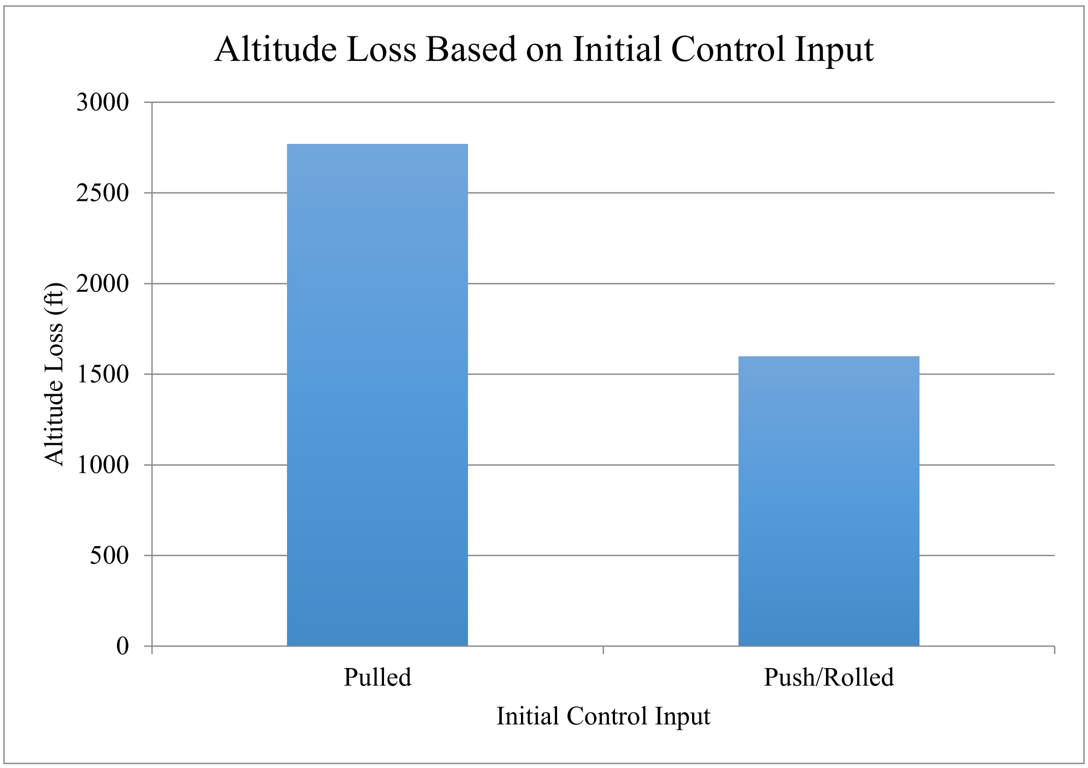


Figure 4. Showing the mean altitude loss during recovery based on the initial control input by the pilot.

Initial Physical Reaction

A chi square test of independence was conducted to determine if there was a significant difference in the initial physical reaction of the pilots when recovering from the aircraft upset. The null hypothesis was there was no dependency between experience and the initial reaction to the aircraft upset based on having upset recovery training or not having upset recovery training when inadvertently placed in upset situations. The chi-square test for independence showed a significant relationship experience and initial physical reaction at the alpha level of .05, χ^2 (1) = 5.900, p = .015 (see Figure 5). The null hypothesis was rejected.

Figure 5.

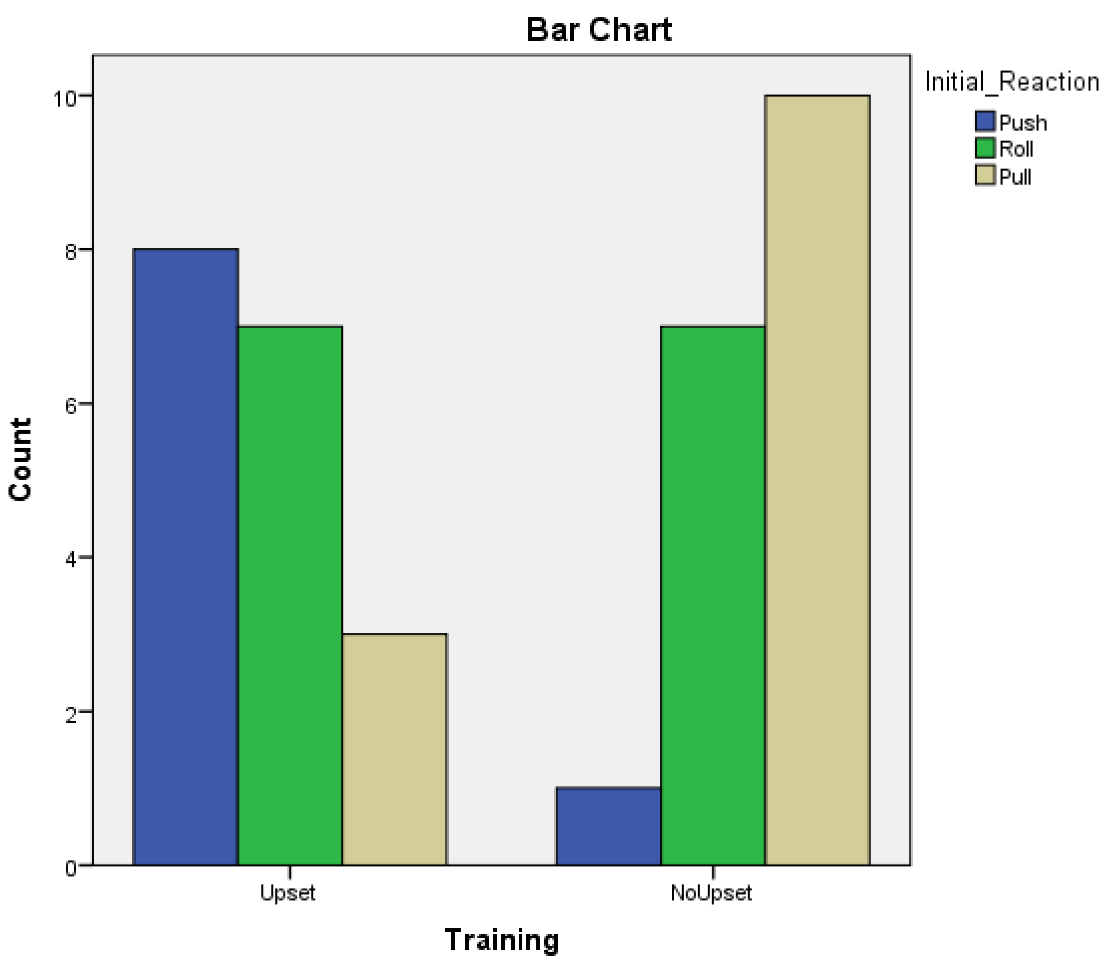


Figure 4. Showing the count of the initial physical reaction for pilots who had upset recovery training and pilots who did not have upset recovery training.

Chapter V

Discussion, Conclusions, and Recommendations

Discussions

Altitude loss. Altitude loss is a critical factor in recovering from an upset situation especially if the aircraft is in close proximity to the ground. Upset recovery training on control inputs should include techniques on how to recover from inverted flight. On the other hand, pilots with no form of upset recovery training may be unaware of such techniques. This difference in upset recovery would explain the significant difference in altitude loss between the upset recovery group and the no upset recovery group. If pilots are trained on how to recover properly they should recover with a lower loss in altitude conversely. Failure to receive such training may result in poor recovery techniques leading to a greater loss of altitude.

Reaction time. Reaction time in this study was the time the pilot took to initially physically react to the aircraft upset. Reaction time in inadvertent upset situations is vital to the successful recovery because seconds can equate to hundreds of feet loss in altitude. Research conducted by Ando et al (2002) states that reaction time decreases with practice, this would explain why there was a significant difference in reaction times between the upset recovery group and the no upset recovery group.

Vertical g-force. There was no significant difference in the maximum g-load between the upset recovery group and the no upset recovery group. The reason for this could be due to the lack of realism in the FTD since it cannot simulate G-Force. In the upset recovery courses, students receive training on how to use their bodies to determine the approximate G-load on the airplane when recovering form upset situations. Lacking this characteristic in the simulator could have contributed to a reduction in realism in terms of recovery procedures.

Time to recover. Time to recover is the amount of time from when the aircraft rolled into an inverted attitude to the time when the pilot was able to attain a bank angle of $\pm$ 5 degrees of level flight and achieve a positive rate of climb. No matter what technique the pilot used to recover from the inverted scenario the recovery time for coming to a complete recovery based on the data was the same. However the quality of the recovery was different in terms of altitude loss, reaction time and initial control input. Regardless of the pilots' level of exposure to upset recovery training, there was no significant difference in the Recovery Times. Any pilot may be able to recover from inverted scenario in a given amount of time. However, a pilot that is trained on how to recover will do so properly in the same amount of time. Proper recovery in this scenario meaning with less stress on the airplane and with minimal loss of altitude.

Altitude loss based on initial reaction. There was a significant difference in the altitude loss based on the initial reaction of pilots in this experiment. A common error for pilots is to follow their instinct of pulling during inverted flight situations due to the decrease in altitude and the increase in airspeed. However, this is the exact opposite of what should be done. In inverted recoveries the actions that should be taken are to push and roll to the nearest horizon (Crawford, 2009). Regardless, pushing or rolling initially led to a lower loss of altitude. If pilots had received upset recovery training they would have been taught this principle ignoring their initial tendency to pull in a descending condition. This is because in upset recovery training pilots practice there recoveries and are conditioned to ignore their instincts.

Initial Physical Reaction. In upset recovery training student are exposed to techniques used to recover from upset flight attitudes. In inverted recoveries the actions that should be taken are to push and roll to the nearest horizon (Crawford, 2009), if a pilot did not receive any form of upset recovery training they may not be aware of such techniques. Pilots are often taught that if the airplane is descending or if you see the ground add back pressure to gain altitude, this then becomes the norm; however, it is the opposite of what should be done in inverted flight. A loss of situation awareness resulting for a failure of Level 1 situation awareness may have attributed to this due to the lack of knowledge related to inverted flight (Endsley, & Jones, 2011). Level 1 situation awareness is referred to as the perception of the elements in the environment. In this case, pilots without upset recovery training were possibly unable to perceive the elements correctly due to a lack of knowledge and or experience in terms of upset recovery techniques.

Conclusions

Some findings of this research were conclusive and some findings were inconclusive. The researcher ran multiple independent sample *t*- tests to tests if there was a significant difference in the Initial Reaction Times, the Maximum G-Load, the Altitude Loss, and the Time to Recover based on having Upset Recovery Training or not having Upset Recovery Training when inadvertently placed in upset situations. Based on the analysis of the data obtained from the FTD it can be concluded that there is a significant difference in the Altitude Loss and the Initial Reaction Times based on having Upset Recovery Training or not having Upset Recovery Training when inadvertently placed in upset situations. Differences in Maximum G-Load and Recovery Time based on having Upset Recovery Training or not having Upset Recovery Training when inadvertently placed in upset situations were not significant . Lastly, it can be concluded that pulling in an attempt to recover from an aircraft upset will cause the greatest loss in altitude. Having upset recovery training has a positive significant effect on how pilots react and recover from aircraft upset situations in terms of altitude loss and reaction time.

Having upset recovery training gives pilots the fundamental knowledge they may need to recover from aircraft upsets. The initial reactions made in inadvertent upset situations are dependent on if the pilot has received upset recovery training or not, i.e. pilots that have upset recovery training learn the correct actions to take when rolled inverted inadvertently whereas pilot without upset recovery training may react incorrectly.

Recommendations

Based on the result obtained the researcher recommends further researcher to be conducted on upset recovery training with the use of an actual airplane to obtain results and reactions from the pilots that may be more realistic. Based on the findings of this study the researcher recommends that the FAA incorporates some form of upset recovery training into pilot certifications at all levels.

References

Ando, S., Kida, N., & Oda, S. (2002). Practice effects on reaction time for peripheral and central vision fields. *Perception and Motor Skills,* 95, 747-751.

Boeing Commercial Airplanes Group. (2014). *Statistical summary of commercial jet airplane accidents*: Worldwide operations, 1959 – 2014. Seattle, WA: Boeing.

Belcastro, C. M., & Foster, J. V. (2010). A*ircraft loss of control accident analysis*.paper presented at *AIAA Guidance, Navigation, and Control Conference,.* Toronto, Canada: American Institute of Aeronautics and Astronautics.

Commercial Aviation Safety Team. (2000). *JSAT loss of control.* Retrieved from http://www.cast-safety.org/pdf/jsat_loss-control.pdf

Crawford, B. (2009). Unusual attitudes and the aerodynamics of maneuvering flight. Retrieved from http://www.flightlab.net/Flightlab.net/Download_Course_Notes_files/FLNotebookpdfs.pdf

Dillman, B. G., & Stanley, D. L. (2003). Upset recovery training in collegiate flight programs. *Collegiate Aviation Review*, *21*(1), 18-26.

Driskell, J. E., Copper, C., & Moran, A. (1994). Does mental practice enhance performance? *Journal of Applied Psychology, 79,* 481-492. doi:10.1037/0021-9010.79.4.481

Endsley, M. R., & Jones, D. G. (2012;2011;2003;). *Designing for situation awareness: An approach to user-centered design* (Second ed.). Boca Raton, FL: CRC Press.

Federal Aviation Administration. (2008). Aeronautical Decision Making. *Pilot's Handbook of Aeronautical Knowledge.* (pp.386). Retrieved from https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/pilot_handbook/media/FAA-H-8083-25A.pdf

Federal Aviation Administration. (2002). Private pilot practical test standards for airplane (SEL, MEL, SES, MES) (FAA-S-8081-14A with Change 1). Retrieved from http://www.faa.gov/training_testingl testing/airmen/test_ standards/pilot/media/F AA-S-8081-14A.pdf

International Air Transport Association. (2015). *Loss of control in-flight accident analysis report.* Montreal. Retrieved from https://www.iata.org/whatwedo/safety/Documents/LOC-I-1st-Ed-2015.pdf

Ison, D. (2014). Correlates of continued visual flight rules (VFR) into instrument meteorological conditions (IMC) general aviation accidents. *Journal of Aviation/Aerospace Education & Research, 24*, 1-26.

Kochan, J. A., Breiter, E. G., Hilscher, M. B., & Priest, J. E. (2005). Pilots perceptions and retention of in-flight upset recovery training: Evidence for review and practice. *Human Factors and Ergonomics Society Annual Meeting Proceedings, 49*(3), 371-375. doi:10.1177/154193120504900333

Rogers, R. O. (2003). Alternative paradigms for structuring collegiate flight programs. *Journal of Aviation/Aerospace Education & Research, 12*(3), 21-30.

Rogers, R. O., Boquet, A., Howell, C., & DeJohn, C. (2010). A two-group experiment to measure simulator-based upset recovery training transfer. *International Journal of Applied Aviation Studies*, *10*, 153-168.

Stolzer, A., & Halford, C. (2004). Quality in airline safety: Quality methods and tools are needed to manage new directions. *Journal of Aviation/Aerospace Education & Research, 13*(3), 27-32.

Wiegmann, D. A., Goh, J., & O'Hare, D. (2002). The role of situation assessment and flight experience in pilots' decisions to continue visual flight rules flight into adverse weather. *Human Factors, 44*, 189-197.

Appendix A

Permission to Conduct Research

Embry-Riddle Aeronautical University
Application for IRB Approval
Expedited Determination

Principle Investigator: Trevor Devaughn Bourne Jr. **Other Investigators:** Dr. Andy Dattel
Role: Student **Campus:** World Wide **College:** COA

Project Title: *The Effect of Upset Recovery Training on the Initial Pilot Reaction During an Inadvertent Upset Situation*

Submission Date: 6/28/2016 **Determination Date:** 7/15/2016

Review Board Use Only

Exempt: No

Approved: M.B. McLatchey ______________________________
Chair of the IRB Signature

Brief Description: Simulation study using the Cessna 172 FTD. This study will contribute to the body of existing knowledge by providing information on if having upset recovery training or not will have an effect on the initial reaction of pilots as well as their recovery techniques to see if there are ways to reduce accident attributed to human error in upset situations.

This research falls under the **expedited** category as per 45 CFR 46.110 under:

> Research activities that (1) present no more than minimal risk to human subjects, and (2) involve only procedures listed in one or more of the following categories. The activities listed should not be deemed to be of minimal risk simply because they are included on this list. Inclusion on this list merely means that the activity is eligible for review through the expedited review procedure when the specific circumstances of the proposed research involve no more than minimal risk to human subjects. (Bankert & Amdur 2006)

1. ☐ Prospective collection of biological specimens for research purposes by noninvasive means.

2. ☐ Collection of data from voice, video, digital, or image recordings made for research purposes.

3. ☒ Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.) [This means research that presents *more than minimal risk to human subjects.*]

Bankert, E. A., Amdur, R. J., (2006) *Institutional Review Board Management and Function, Second Edition*, pp. 517-518.

Embry-Riddle Aeronautical University
Human Subject Protocol Application Form

Campus: Daytona Beach **College:** Aviation - Daytona & Prescott

☐ Non-ERAU/Other Institution
Name & Address:

Applicant: Student **Degree Level:** Master

Project Title: The Effect of Upset Recovery Training on the Initial Pilot Reaction During An Inadvertent Upset

Principal Investigator: Trevor Devaughn Bourne Jr.

(If undergraduate student, faculty advisor must be listed as the principal investig

List all Other Investigators: Dr. Andy Dattel

(If graduate student, list research advisor and all other investigators.)

Submission Date: 06/24/2016

Beginning Date: 07/11/2016 **Expected End Date:** 06/30/2017
(Approval is only good for one year.)

Type of Project: (Check ALL that apply.)

☐ Survey ☐ Interviews ☐ Classroom ☐ Use of Existing Data

☐ Comparison of instructional strategies ☐ Observation of public behavior

☐ Audio/Video recording ☑ Other Explain:

Type of Funding Support (if any):

☐ **Internal**

- ☐ Faculty Internal Award
- ☐ Student Internal Award
- ☐ IGNITE Funds
- ☐ CTLE Funds

☐ **External** If externally funded what agency?

☐ **Other** Explain: Simulation study using the Cessna 172 FTD

☑ **Not Funded**

Please answer the following questions and provide a brief explanation of the answer for each.

1. **Background and Purpose: Briefly describe the background and purpose of the research including your hypothesis or primary objective and its rationale.**

Across the aviation industry worldwide, loss of control in flight remains the number one cause for fatal accidents, with only 30% of those accidents being the result of a system or component malfunction (Belcastro & Foster, 2010). Most loss of control mishaps result from pilots making the incorrect inputs that is if inputs are even made on the controls, which may be prevented and or mitigated by implementing upset recovery training techniques into pilot training. The purpose of this study is to see if upset recovery training has a positive impact on potentially reducing accidents. Another aim of this study is to evaluate from a simulation standpoint if pilots are divided into two groups, one group having upset recovery training and the other having no upset recovery training; will there be a difference in the reaction time, altitude loss and g loading of the aircraft when recovering from upset situations

Please describe briefly how this study will contribute to existing knowledge in the field

This study will contribute to the body of existing knowledge by providing information on if having upset recovery training or not will have an effect on the initial reaction of pilots as well as their recovery techniques to see if there are ways to reduce accident attributed to human error in upset situations.

2. **Design, Procedures, Materials and Methods: Describe the details of the procedure to be used and the type of data that will be collected.**

This research design is a quasi-experimental research study. The research design with be a 2 x 2 mixed factorial design The two between subject factors will be upset recovery and no upset recovery experience and the within subject factors will be scenarios one and two. The two independent variables are upset experience and the scenarios. The dependent variables will be g loading (the amount of G's) pulled during recovery, altitude loss and reaction time. The data will all be exported to a Microsoft excel spreadsheet from the Fracsca Level 6 C172 FTD data logs. The type of data to be collected will all be quantitative.

The total duration required of each participant will be approximately 10 minutes, with each scenario taking around 5

3. **Measures and Observations: What measures or observations will be taken in the study? If any questionnaires, tests, or other instruments are used, provide a brief description <u>and</u> include a copy for review (computer programs may require demonstration at the request of the IRB).**

The only measures that will be involved in this study is the data extracted from the Frasca Level 6 C172 FTD data logs.

4. **Risks and Benefits: Describe any potential risks to the dignity, rights, health or welfare of the human subjects. Assess the potential benefits to be gained by the subjects as well as to society in general as a result of this project. Briefly assess the risk-benefit ratio.**

Participants may experience some motion sickness however, this is highly unlikely due to the participants exposure to this FTD in the past. Participants will be briefed that if they feel uncomfortable at any time let the researcher know and the study will be terminated for that specific participant. Other risks that may be associated with this study are no greater than those encountered in everyday life. Based on the potential results of this study it could be found that having upset recovery experience may or may not have an effect on a pilot's initial reaction and their recovery technique. Based on the findings from the study, it can be used by the FAA and NTSB to make recommendations and/or regulations. Participants that have no upset experience may see the potential benefit of upset recovery training and may elect to take

5. Informed Consent: Describe the procedures you will use to obtain informed consent of the subjects and the debrief/feedback that will be provided to participants. See Informed Consent Guidelines for more information on Informed Consent requirements. **(The consent document must be submitted with this application for review.)**

Upon meeting the participant the researcher will issue an informed consent as attached to this document.

6. Anonymity: Will participant information be: **(Check appropriate box.)**

☐ **Anonymous (not even the researcher can match data with names)**

☑ **Confidential (names or any other identifying demographics can be matched, but only members of the research team will have access to that information. Publication of the data will not include any identifying information)**

☐ **Public (names and data will be matched and individuals outside of the research team will have either direct or indirect access. Publication of the data will allow either directly or indirectly, identification of the participants).**

Justify the classification and describe how privacy will be ensured/protected.

Participants will be assigned a random participant ID with odd ID numbers identifying participants from the upset recovery experience group and even numbers identifying members from the no upset experience group. The files that will be extracted for data analysis will include the participant ID in an effort to categorize the data into the upset experience or no upset experience group. Upon completion of data collection, this data will be placed into an excel spreadsheet. This data will be saved on a flash drive in a password protected excel file that only belongs to the researcher and the research advisor.

7. Privacy: Describe the safeguards (including confidentiality safeguards) you will use to minimize the risks. If video/audio recordings are part of the research, please describe how that data will be stored or destroyed.

Participants will meet researcher at a time agreed upon at the Advanced Flight Simulation Center (AFSC). The participant will be briefed and brought into the simulation bay and the researcher will run the scenarios, upon completion the participant will be free to depart the AFSC. The data will be extracted and saved as mentioned in the procedure above. This data will be saved on a flash drive in a password protected excel file that only belongs to the researcher and the research advisor.

8. Participant Population and Recruitment Procedures: Who will be recruited to be participants and how will they be recruited. Note that participants must be at least 18 years of age to participate. Participants under 18 years of age must have a parent or guardian sign the informed consent document.

A recruitment email will be sent out to all active pilots at Embry-Riddle Aeronautical University (ERAU) asking for participation in this study, posters will also be posted around the (ERAU) campus in the flight line, Collage of Aviation (COA) and the Advanced Flight Simulator Center (AFSC). For the propose of this study, active pilots will be any pilot who has flown in excess of 10 hours in the past 30 days. Participants must possess at least a commercial pilot certificate or having a private pilot certificate and in excess of 250 flight hours. Two categories will be identified: (a) upset recovery experience and (b) no upset recovery experience. The participants' exposure to upset recovery training will

9. Economic Considerations: Are participants going to be paid for their participation? If yes, describe your policy for dealing with participants who 1) Show up for research, but refuse informed consent; 2) Start but fail to complete research.

No compensation for participating in this study

10. Time: Approximately how much time will be required of each participant?

10 Minutes

By signing below and returning this application, you are signing that as the Principal Investigator as well as any other investigators certify the following:

1) The information in this application is accurate and complete
2) All procedures performed during this project will be conducted by individuals legally and responsibly entitled to do so
3) I/we will comply with all federal, state, and institutional policies and procedures to protect human subjects in research
4) I/we will assure that the consent process and research procedures as described herein are followed with every participant in the research
5) That any significant systematic deviation from the submitted protocol (for example, a change in the principal investigator, sponsorship, research purposes, participant recruitment procedures, research methodology, risks and benefits, or consent procedures) will be submitted to the IRB for approval prior to its implementation
6) I/we will promptly report any adverse events to the IRB.

______________________	06/23/2016
Signature of Principal Investigator	Date
______________________	______________________
Signature of Faculty Advisor	Date

July 2015

AGREEMENT TO PARTICIPATE IN

The Effect of Upset Recovery Training on the Initial Pilot Reaction during an Inadvertent Upset Situation

STUDY LEADERSHIP. You are invited to participate in a research study that is being conducted by Trevor Bourne, a student in the Masters of Science in Aeronautics Program in partial fulfillment of his degree requirement for the course MSA 691 (Graduate Capstone Research Project) under the guidance of Dr. Andy Dattel, Assistant Professor.

PURPOSE. The purpose of this study is to see understand pilots reactions to upset recovery.

ELIGIBILITY. To be in this study, you must be 18 years or older, hold at least a commercial pilot certificate, or hold a private pilot certificate and have 250 flight hours or more. Participants must have flown10 hours in an airplane within the preceding 30 days.

PARTICIPATION. During the study, you will be placed into different scenarios in the C172 Flight Training Device (FTD) and will be required to resolve them to the best of your ability. Your involvement in this study will be approximately 10 minutes.

RISKS OF PARTICIPATION. The risks of participating in this study are minimal no more than risks associated with everyday life. Because you are flying in a simulated aviation environment, there is the potential that you may experience motion sickness; however, this is unlikely because of your exposure to this device in the past. If you experience motion sickness, let the experimenter know and the scenario will be immediately stopped.

BENEFITS OF PARTICIPATION. Your participation in this study will help us understand pilot's initial reaction and their recovery technique. Based on the findings from the study, it can be used by the FAA and NTSB to make recommendations and/or regulations.

COMPENSATION. There is no economical compensation in this research.

VOLUNTARY PARTICIPATION. Your participation in this study is voluntary. You may stop or withdraw from the study at any time without penalty. Your decision whether or not to participate will have no effect on your current or future connection with anyone at ERAU.

RESPONDENT PRIVACY. The data recorded of your performance will be exported to an excel spreadsheet. Only myself (Trevor Bourne) and the faculty advisor (Dr. Andy Dattel) for this study will have access to the data recorded in the spreadsheet. In order to protect the confidentiality of your results, any collected data or personal information will be entered and stored in a password protected file. To maximize anonymity, I will provide each participant with a random ID for the study. Therefore, your name will not be associated with your data. The data will be stored for 3 years after completion of this study, and will then be deleted.

FURTHER INFORMATION. If you have any questions or would like additional information about this study, please contact Trevor Bourne at (407)-435-9358 or via email at bournet1@erau.edu or Dr. Andy Dattel at (386) 226-7795 (andy.dattel@erau.edu).

The ERAU Institutional Review Board (IRB) has approved this project. You may contact the ERAU IRB with any questions or issues at (386) 226-7179 or teri.gabriel@erau.edu. ERAU's IRB is registered with the Department of Health & Human Services – Number – IORG0004370.

CONSENT. Your signature below means that you understand the information on this form, that any and all questions you may have about this study have been answered, and you voluntarily agree to participate in it. A copy of this form can also be requested from Trevor Bourne.

Signature of Participant ____________________ Date ___________

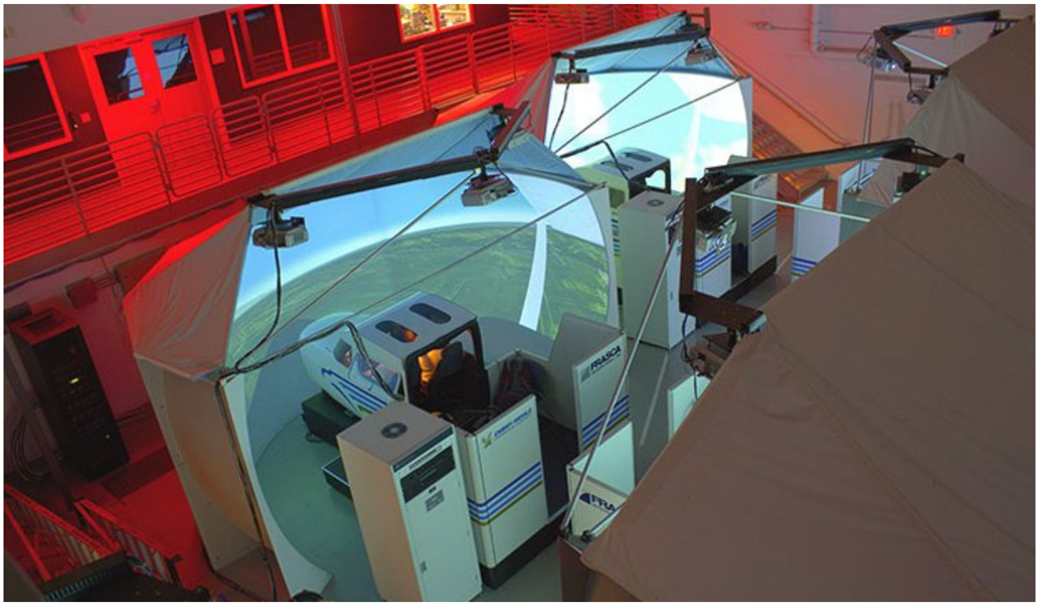
Print Name of Participant ____

Signature of Researcher _____________________ Date_____________

Appendix B

Data Collection Device

B1. Picture of the F-172 FTD



Adapted from http://daytonabeach.erau.edu/about/fleetsimulators/frasca-c172/index.html

B2. Experiment pre-brief

The following statement was read to the participants prior to starting the experiment. “Thank you for agreement to participate in this study. Once you enter the FTD you will be on an IFR flight plan in contact with Daytona Beach approach on 125.800 at 6000 feet direct to the Melbourne International Airport. Once you are seated in the cockpit go ahead and program the G1000 direct to KMLB and let me know when your are situated and ready for the simulation to be un-paused. Do you have any questions?”

Appendix C

Tables

C1 Experimental Design

Scenario	Experience Level	
	Upset Recovery	No Upset Recovery
1	Participant ID#3 (d,e,f,g,h)	Participant ID#2 (d,e,f,g,h)

Note. d = altitude loss, e = g-load, f = reaction time, g= initial reaction, h= time to recover

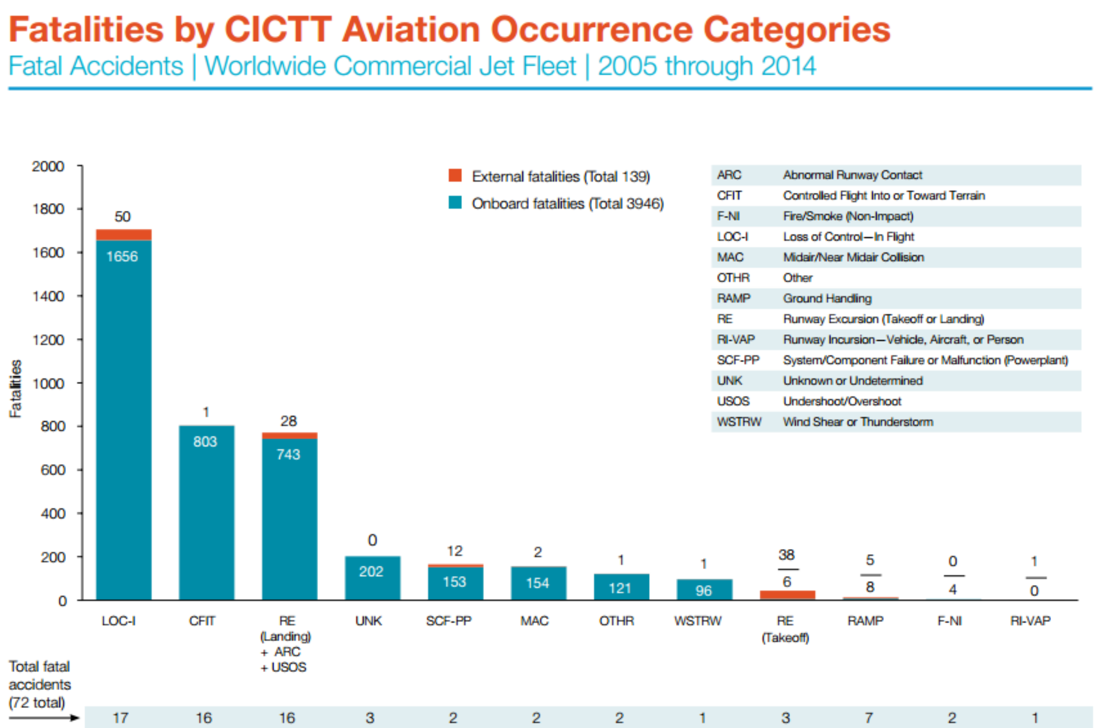
C2 Descriptive Statistics for pilots who had upset recovery training and pilots who did not have upset recovery training.

Variables	Group	N	Minimum	Maximum	Mean	Standard Deviation
Altitude Loss (Feet)	Upset Experience	18	726	3032.03	1674.07	747.99
	No Upset Experience	18	1044	3986.04	2365.41	779.79
Maximum G-Load (G's)	Upset Experience	18	1.57	3.67	2.68	0.619
	No Upset Experience	18	1.72	3.5	2.72	0.47
Reaction Time (Seconds)	Upset Experience	18	0.8	2.2	1.41	0.35
	No Upset Experience	18	0.7	3.2	1.83	0.74
Time to Recover (Seconds)	Upset Experience	18	5.4	24.4	12.97	4.83
	No Upset Experience	18	9.2	30	15.52	4.72

Appendix D

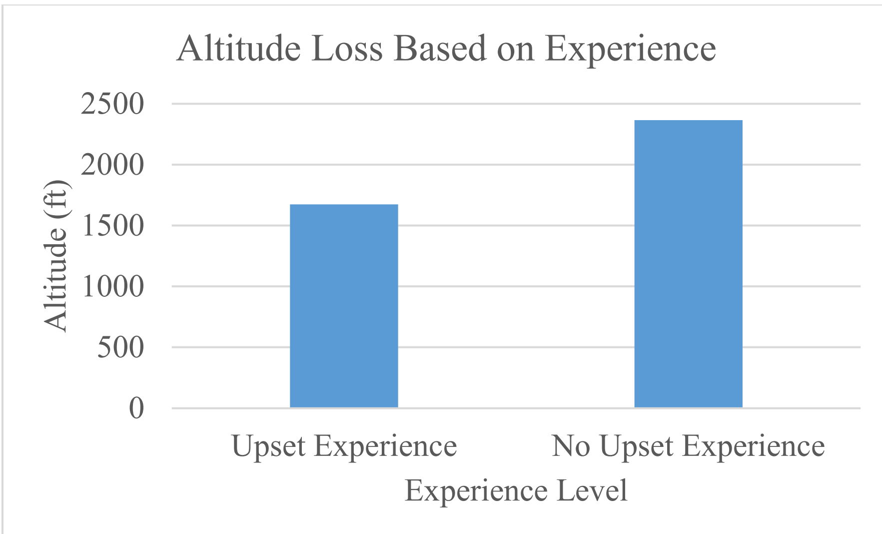
Figures

D1 Displaying fatalities by CICTT Aviation Occurrence Categories between the years of 2005-2014.

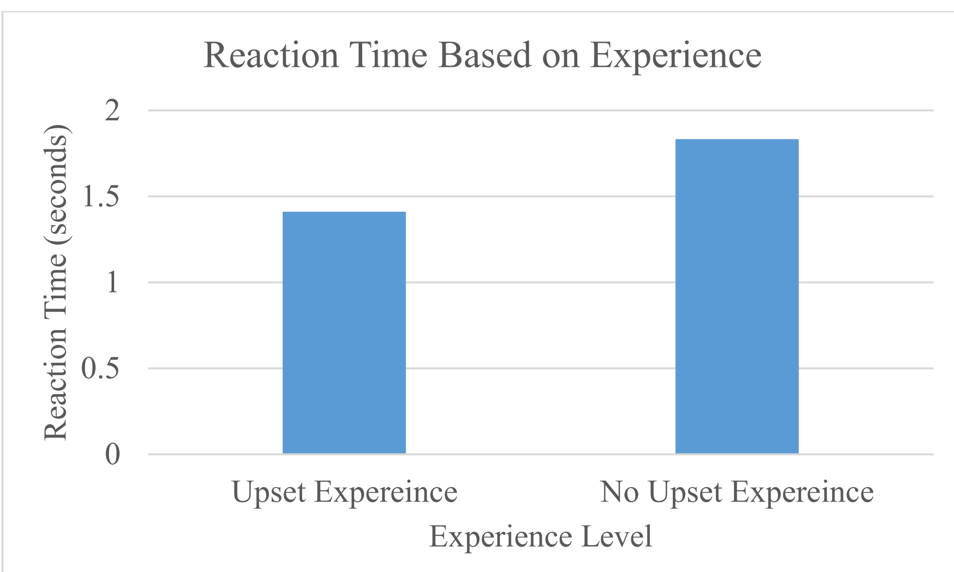


Adapted from Boeing Commercial Airplanes Group (2014). Statistical summary of commercial jet airplane accidents: Worldwide operations 1959 – 2014. Seattle WA: Airplane Safety.

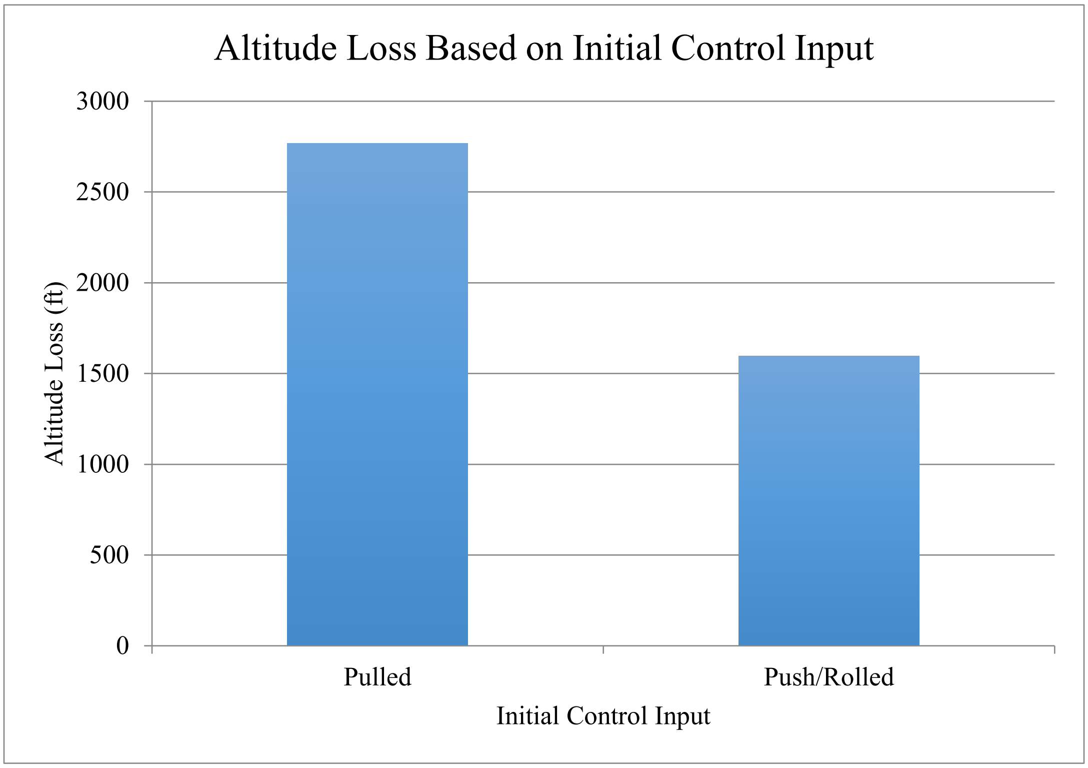
D2 Showing the mean altitude loss during recovery from the aircraft upset for pilots whom had upset recovery training and pilots who did not have upset recovery training.



D3 Showing the mean initial physical reaction times for pilots who had upset recovery training and pilots who did not have upset recovery training.



D4 Showing the mean altitude loss during recovery based on the initial control input by the pilot.



D5 Showing the count of the initial physical reaction for pilots who had upset recovery training and pilots who did not have upset recovery training.