January 2018

A Comparative Analysis Of Manned And Unmanned Aviators's Approach To Safety

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Recommended Citation

Dahl, Aaron Marlo, "A Comparative Analysis Of Manned And Unmanned Aviators's Approach To Safety" (2018). *Theses and Dissertations*. 2194.
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A COMPARATIVE ANALYSIS OF MANNED AND UNMANNED AVIATORS' APPROACH TO SAFETY

by

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A Thesis

Submitted to the Graduate Faculty

of the

University of North Dakota

In partial fulfillment of the requirements

for the degree of

Master of Science

Grand Forks, North Dakota
May
2018

This thesis, submitted by Aaron M. Dahl is partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done, and is hereby approved.

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Grant McGimpsey
Dean of the School of Graduate Studies

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Date

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Department	Aviation
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Aaron M. Dahl
April 23, 2018

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ACKNOWLEDGMENTS

Thank you to those that assisted and guided me throughout my time in the master’s program at the University of North Dakota.

ABSTRACT

This study is an analysis of differences between unmanned and manned aviation industry safety. A survey tool was used to collect safety perception, risk perception, and organizational safety culture data from various individuals throughout the aviation industry. In general, no difference existed between the unmanned and manned groups, indicating an overall safe operating environment for aviators. While the results of this limited study show no overall difference between groups, it provides a baseline study for which future data, collected from a more mature industry, can be obtained.

CHAPTER I

INTRODUCTION

> *"I was always afraid of dying. Always. It was my fear that made me learn everything I could about my airplane and my emergency equipment, and kept me flying respectful of my machine and always alert in the cockpit."*
>
> *Chuck Yeager*

True to their name, operators or pilots control unmanned aircraft from remote locations ranging from mere feet to thousands of miles. Technological advancements further increase unmanned aircraft operators' ability to expand the physical distance between themselves and the aircraft. A typical unmanned aircraft system consists "of an unmanned or remotely piloted aircraft, the human element, payload, control elements, and data link communication architecture" (Barnhart, et al., 2015, p.17). The safety and reliability of the non-human aspects of these systems benefit from increasing technological capabilities and increased reliability of redundant control methods (Bolkcom, 2004). While the unmanned aircraft industry continues to benefit from new technology, it is possible that taking the human out of the aircraft may pose adverse consequences. The Department of Defense (DoD) "estimated that UASs suffered accidents at a rate of 10 to 100 times that of what is observed in manned aircraft, with operator error accounting for approximately 20 percent of all mishaps" (Barnhart, et al., 2015, p.166). In a report for Congress, Bolkcom adds, “If control systems fail in a manned aircraft, a well-trained pilot is better positioned to find the source of the problem because of his/her physical proximity” (Bolkcom, 2004, p.4). These statements suggest removing the pilot from the aircraft decreases the operator’s capability to understand the environment in which the aircraft operates.

Few will debate unmanned aircraft systems bring about not only new technology but also a psychological shift and a new approach to operating aircraft in the skies. While crashing an aircraft, manned or unmanned, results in financial loss to stakeholders, removing the physical risk to the operator is a benefit of unmanned technology. Crashing or ditching an aircraft, typically the last resort in normal operations, now may serve as a primary mission function by design.

A common nineteenth-century proverb, “better safe than sorry” exists as the foundation of aviation rulemaking and safety procedures. Beyond that, it describes a culture in which aviators make decisions based on calculated risks and what they believe to be the safest outcome given a specific situation. Any rejection or contradiction of the “better safe than sorry” mindset warrants review. Chuck Yeager learned from the feel of his aircraft and for more than half a century teams of flight test engineers put their lives at stake to help the industry further understand the limitations of flight. Taking human lives out of the cockpit decreases personal risk. However, continuing to the improve the safety of unmanned aircraft operations relies on an increased understanding of physiological and psychological impacts of removing the operator.

Statement of Problem

Unmanned aircraft operator training varies widely due to the numerous types of aircraft that exist for a wide variety of missions. Over time, newly developed training standards and safety initiatives will fit the form and function of the desired operations, whether it be precision agriculture or high-altitude reconnaissance. However, the main benefit of Unmanned Aircraft may prove to be the biggest challenge when approaching safe and efficient operations. The teleoperation of the aircraft from distant locations allows operators to conduct dull, dirty, or dangerous missions from the relative comfort of their ground control station (GCS). Taking the human out of the cockpit minimizes many risks to the operator, most importantly loss of life. Recognition and acknowledgment of psychological and physiological issues related to UAS operation will assist in developing adequate training and creating an environment that fosters the growth of efficient and safe organizations.

Purpose of Study

The purpose of this study is to differentiate the meaning of safety and application thereof in manned and unmanned operations. This study also attempts to examine the impact perception of risk has on operational and organizational safety.

Significance of Study

Unmanned Aircraft usher in a new era in the modern world. UAS represents an entirely new market that will improve and increase the current aviation industry but will also break barriers into other market segments. Soon, civilian and military UAS operations will be carried out within the National Airspace System (NAS) in close coordination with other manned aircraft missions. The confined nature and complexity of the NAS increases the importance of understanding how the introduction of UAS influences the status quo. Rising popularity of UAS across a broad spectrum of industries and hobbyists alludes to increased congestion in the already complex airspace. That is in addition to the remote aircraft operations at any of the Academy of Model Aeronautics' flying clubs that number over 2,500 (Gettinger & Michel, 2015). Near Midair Collision (NMAC) reports concerning UA increased exponentially over the last decade. In a report published by the Federal Aviation Administration (FAA), pilots reported 1,346 potential unmanned aircraft sightings between August 2014 and January 2016 (FAA, 2016). NMAC data and the increasing popularity of civilian UAS further exemplifies the necessity to understand as much as we can about how to operate this new technology safely.

Manned aviators and unmanned operators face many similar situations and are forced to make decisions based on their best interpretation of the available information. They operate with many of the same limitations and under the similar fundamentals. However, what changes when the operator or pilot no longer resides with their aircraft?

This study, limited in scope, attempts to expose areas in which aeronautical decision making differs between manned and unmanned aviators. It will attempt this by looking at how pilots and operators perceive risk, how their organizations approach safety, and how they approach operational safety aspects. Findings may provide essential information as to how UAS and manned aviation are similar and, perhaps more importantly, where the two differ.

Research Questions

The following is a list of primary and secondary questions to be examined:

1. How does the perspective of safety differ between the manned and unmanned aviation industries?
    a. How do organizational safety practices or ideologies compare between manned and unmanned aviation?
    b. How do operational safety practices or ideologies compare between manned and unmanned aviation?
2. Does the potential for loss of life, or the lack thereof, affect the pilot or operator's perception of risk?
    a. How does risk perception alter decision making in routine operations?
    b. How does risk perception alter decision making in emergency operations?
3. Is there a noticeable difference in safety culture when comparing manned and unmanned organizations?

Conceptual Framework

A survey will be used to collect data, assisting in answering the above research questions. Distributed to a diverse population of aviation professionals the survey included aviators or operators with solely UAS, solely manned aviation, and mixed operations background. The information collected will include necessary demographic information as well as details of their career. Again, diversifying the population will remain an essential factor for comparing data and identifying areas where increased focus on safety may be required.

Assumptions

1. Participants in this study are doing so on a volunteer basis.
2. Information collected in the form of responses to survey items is factual to the best of the participants' knowledge.
3. Participants in this survey have received some professional training in either UAS or manned aviation or have received training in both.

Limitations

1. The diversity of the population may provide a multitude of responses in which too many outcomes exist.
2. The background of the participants will vary widely and may decrease the applicability of the survey for some individuals.
3. The survey will be limited to those participants who have received training in either UAS or manned aviation.

CHAPTER II

LITERATURE REVIEW

Nomenclature

An Unmanned Aerial Vehicle (UAV) is an aerial vehicle piloted from a remote location through teleoperation. UAVs are also known as Remotely Operated Vehicles (ROV), Remotely Piloted Vehicles (RPV) and Uninhabited Aerial Vehicles (UAV). In the case of the United States Air Force who dislikes the term vehicle refers to UAVs as Remotely Piloted Aircraft (RPA), drones, or merely Unmanned Aircraft (UA). Unmanned Aircraft (UA) or Unmanned Aircraft Systems (UAS) shall be the primary references throughout this document.

Development of Unmanned Aircraft

The expendability of unmanned aircraft dates back to the roots of aviation. Early aviation pioneers, the likes of Felix du Temple, Alexander Mozhaiski, Octave Chanute, the Wright Brothers, and countless more revolutionaries utilized models and kites to test theories without risking injury or death (Anderson, 2004). Shortly after the Wright Brothers achieved powered, controlled, and sustained flight, inventors began looking for ways to take the humans out of the operation. In 1908, Elmer Sperry developed a navigational gyroscope for the Navy. After the successful testing of his gyroscope in 1911, Sperry adapted the technology to act as a stabilization system for aircraft (Spinetta, 2011). While unreliable, the United States Navy saw enough promise in the technology to offer Sperry a contract to “pack a Curtiss N-9 floatplane with dynamite” and the army to contract fellow pioneer Charles Kettering to create their versions of unmanned aerial torpedoes (Newcome, 2004, Spinetta, 2011, p.3). Simplistic and disposable in design, these primitive UAs performed one way, seek and destroy missions using only basic aeronautical navigation equipment. Throughout the 20th century, unmanned aircraft evolved from aerial torpedoes to remotely piloted target aircraft and eventually to sophisticated, multi-use tools, we recognize today. The modern unmanned aircraft industry developed around equipment similar to the Predator, Global Hawk, Shadow, and Hunter systems. Technology advancements in early 21st century provide both commercial and military markets with advanced tools capable of taking on an ever-expanding role in society and remain expendable regarding human skin in the game. "Dull, dirty, and dangerous" became the tagline for the types of missions UA would perform (Blydenburgh, 1999, p.2). From the sands of the Middle East in support of the United States and foreign militaries to pipeline management in North Dakota, unmanned aircraft perform tasks that remove pilots from harm's way. While modern unmanned systems share little with Sperry's Unmanned Curtiss N-9 floatplane, the absence of human-machine physical connection is the same. To continue the evolution of unmanned aircraft, understanding the effects of separating pilot from aircraft may prove essential is developing policy and doctrine moving forward.

Economic Considerations

In a report by market analyst firm Deloitte Touche Tohmatsu Limited (DTTL) the total civilian UAS industry revenues were predicted to be between $200 million and $400 million (Canis, 2015). Bill Canis, in a Congressional Research Service outlook forecast, adds that total revenue for 2015 including military, civil, and commercial may have reached as high as $3.3 billion (Canis, 2015). The UAS market currently includes precision agriculture, infrastructure maintenance and management, aerial photography, law enforcement, disaster management, telecommunication, weather monitoring, and freight transport to name a few (Jenkins & Vasigh, 2013). While solidifying the use of UAS in these markets is an essential step in developing a UAS industry, innovation, and creative UAS solutions will drive the industry to new heights.

The unmanned market presents an opportunity to add significantly to the economy. In 2013, the Association for Unmanned Vehicle Systems International (AUVSI) released a report titled *The Economic Impact of Unmanned Aircraft Systems Integration in the United States.* In this report Darryl Jenkins and Dr. Bijan Vasigh (2013) conclude “the economic impact of the integration of UAS into the NAS will total more than $13.6 billion in the first three years of integration and will grow sustainably for the foreseeable future, cumulating to more than $82.1 billion between 2015 and 2025” (p.2). Direct and indirect job creation due to the introduction of UAS in the United States is forecasted to produce over 103 thousand new jobs (Jenkins and Vasigh, 2013).

Maximizing these benefits can only be accomplished by ensuring the industry grows. Create safe operating environments and practices will help to increase public perception and acceptance of this tremendous economic opportunity.

Unmanned Safety & Current Regulation

Previous attempts to create preventative or reactive safety measures for unmanned aircraft has proven difficult due to a general lack of available data. Much of the early UA operations in the 1990's and early 2000's existed in the form of Military operations. As such, data regarding those operations is widely unavailable either for proprietary or security reasons. Kevin Williams also suggests that data is hard to obtain, in part, due to the low level of analysis on unmanned accidents and incidents. He explains the decreased analytics is a result of the smaller financial loss to the military in comparison to the loss of a manned asset (Williams, 2004). The transition into the second decade of the 21st century brings with it the promise of expanded UA operations for both military and civilian industries. Beyond accident data, even less data is available in the decision-making processes that UAS operators utilize. Assumptions that UAS operators and manned aviators make decisions and approach safety, in the same way, could prove detrimental to the industry. Understanding how UAS operators perceive risk and approach safety will assist in shaping regulations and ensuring that unmanned specific safety concerns are, at a minimum, held in the same regard as those of manned aviators.

Integration of Unmanned Systems into the National Airspace system exposes several safety concerns. Due to the rapid growth and popularity of UAS, the Federal Aviation Administration found themselves pressured to create regulations to ensure safe operation of UAS integration NAS. Congress, by way of the FAA Modernization and Reform Act of 2012, pushed the FAA to create and implement UAS regulations.

Introduced in late 2016, Federal Aviation Regulation (FAR) Part 107 responded to Congress' call and opened the NAS to small UAS platforms. FAR part 107 addresses many UA operational concerns to include pilot certification and registration; however, it lacks in its impact on safety considerations. Advisory circular AC 107-2 augments 14 CFR part 107 by "promoting compliance" of the regulations and encourages remote pilots to "use this information [AC 107-2] as best practice methods for developing operational programs scaled to specific small unmanned aircraft" (FAA, 2016).

While FAA part 107 represents a move towards integration of UAS into the NAS, further research and analysis must be done to ensure that this step in the right direction continues producing positive results. Analysis of UAS (drone) incident data by Dan Gettinger and Arthur Michel revealed several concerning statistics. They found that "over 90 percent of all incidents occurred above 400 feet" and "within five miles of an airport" (Gettinger & Michel, 2015, p. executive summary). Moreover, while this report preceded the release of FAA Part 107, it shows a violation of the AC 91-57A *Model Aircraft Operating Standards*, which shares similar altitude and weight restrictions with the FAA's regulations.

Understanding causes of UAS incidents and accidents pave the way to a more productive and efficient industry. Are UAS operators receiving appropriate training? How do UAS operators view flying? What level of severity do they apply to potential incidents?

Current Safety Initiatives Aviation Safety Programs

Reviewing current safety initiatives and programs is essential in further understanding how to approach specific unmanned aviation safety protocols.

Risk Perception

Perceiving risks in a given scenario affects decision-making. Torbjorn Rundmo discusses the matter of risk perception as a difference between objective and subjective perception. Rundmo states, “employees’ perception of risk as well as their subjective assessments of the working conditions and work environment can be important for the personnel’s behavior with regards to risk and hence may also influence objective risk or safety” (Rundmo, 1996, p.197). Consequences should play a role in risk perception and estimation. In regards to pilots’ perception of flight, David Hunter found that “pilots substantially underestimated the risk of general aviation flying relative to other activities” and additionally states, “the viewer [participant] must, therefore, perceive accurately not only the external situation but also their personal capacities. (Hunter, 2002, p.3). Together risk perception and personal capacities should be taken into account when making decisions. Rundmo suggests that risk perception is tied directly to their risk behavior.

Perception of risk in aviation, as it is in many facets of life, directly influences the decision-making process and is ultimately affected by several factors. Rundmo suggests that our “biased perception of risk can cause misjudgments of potentially hazardous risk sources” (Rundmo, 1996, p.198). Personal experience, background, education, and several other factors shape opinions of classifying high and low-risk activities. For example, pilots with minimal IFR training may view flight in IMC conditions as more hazardous that pilots with years of experience. Similarly, a UAS operator with little experience in a particular situation may deem a flight high-risk when an operator more familiar with the locale would not. In both examples, the equipment, flight path, weather, mission, and flight plan could all be the same. However, the outcome of the operation might drastically change due to the decision making of the pilot (operator) based on their perception of risk in the given operation. Understanding these variables can be extremely difficult. Orasanu, Fischer, and Davison (2002) point out that incorrect interpretation of important cues contributes to the inappropriate assessment of risk, failing to update one's situation model. Orasanu, Fischer, and Davison continue to explain how, "perception of risks and the decisions that follow are influenced both by individual cognitive factors, as well as by organizational pressures relating to company productivity, economics, and its safety culture" (p.2).

Application of studying risk perception in UAS operations may be complicated, but this study aims to depict why it deserves attention. Aviators occupying the cockpit of a cargo airliner must perform on schedule and operate at peak efficiency while maintaining a high standard of safety. If weather moves into the departure airport, the pilot must decide to go or not. Decision making may get more complicated if he has a family at home waiting for him. That external pressure, to arrive home, may be enough for the pilot to outweigh the inclement weather and take off in a perceived risky situation.

Alternatively, the external pressures, both professional and personal, were enough to lower the pilot's perception of the risk. Would a UAS operator given the same situation make the same decision? What external pressures drive risk perception in UAS operations? If the operator gets to go home for Christmas regardless of the outcome of the flight, would they make a more informed decision with less influence from personal pressures? Or would the company's goals and the perceived lower risk due to no threat to life outweigh the weather situation? The easy answer is that regulation and policy would dictate the decision. Does the company policy and FAA allow for flight in this situation? Well this study, as with previous risk perception studies, attempts to analyze the gray area. What drives decision making when no one is watching?

Risk Tolerance

"Anything is safe if its risks are judged to be acceptable (Gill, 2004, p.44). David Hunter defines risk tolerance as "the amount of risk that an individual is willing to accept in the pursuit of some goal" (Hunter, 2002, p.3). Applying this sentiment to aviation, risk tolerance plays into how pilots make decisions. Hunter concluded, "Perception of risk is negatively related to tolerance for risk" (Hunter, 2002, p.20). In UAS operations, an operator's risk is minimal. Determining how an operator tolerates or judges risk may help to predict the safety of a given operation. It is interesting to consider the idea that a pilot may tolerate less risk in a given scenario where a UAS operator with no personal risk to life, may tolerate a much higher risk. Hunter's study suggests age, profession, and other factors influence the amount of risk tolerance in an individual.

Summary of Literature Review

Disposable by nature, unmanned aircraft present opportunities to explore areas that would previously place pilots in harm's way. This review of the available literature exposes a lack of studies examining connections between risk perceptions and self-preservation. Links exist between various parallel industry studies such as Rundmo's study of oilrig employees in Norway. Analyzing available accident/incident data provides a broader picture of the UAS industry safety outlook. Current data is limited; however, this review of literature included information from a few of the available studies and concluded that human factors are present in a high percent of UAS mishaps. While cockpit design, haptic feedback, and other physical human factor concerns are more frequently studied, UAS operator's perception and tolerance of risk are generally under-analyzed. This study will attempt to explore differences that exist when the fate of the pilot is not tied to that of their aircraft.

CHAPTER III

METHOD

Unmanned technology and automation further perpetuate the different human factors facing UAS operators. This study explores the relationship of several key attributes of UA operations and how they affect the decision making and safety perception of the crew. The literature review did not include a study that focused on these issues and as such leaves potential gaps in training and doctrine that may lead to new dangerous attitudes if left unchecked. This study utilizes a survey designed to expose different perceptions of safety when comparing the manned and unmanned aviation industries.

Population

The participants in this study will be asked to self-identify as either a military UAS operator, Civilian UAS operator, Commercial Pilot, general aviation pilot, hobbyist UA operator, or other, ensuring inclusion of a significant portion of professional and general aviators. After self-identifying, questions will be designed to reveal the level of experience the participant has in both UAS and manned aviation. This population could pose challenging to study due to the mixed bias of a participant with experience in both UAS and manned aviation. For example, United States military UA operators present diverse backgrounds. United States Army operators are typically young, enlisted soldiers with minimal flight experience whereas United States Navy operators undergo significant manned flight training before unmanned operations. Diversifying the participant population will increase the scale of the survey but may lead to specific areas in which to conduct further research.

Data Collection

This survey, produced and distributed using Qualtrics®, a web-based survey tool, was distributed through electronic means. Participants first provided demographic data used to identify various groups within the overall population and to establish a baseline for data analysis upon completion of the survey. The author of this study has an undergraduate degree in Unmanned Aircraft Systems Operations and currently works for a leader in the UAS industry. The author used this knowledge to develop twenty-nine survey items designed to address the three research questions.

Sample

This study aimed to target no less than 100 individuals in an attempt to diversify the demographics of the participants while maintaining the applicability of the results. An equilibrium among demographics would further increase the stability of resulting data.

Demographics

Distribution of the survey via electronic methods increased the opportunity for participants in multiple regions and professions to take part in the study. This research targets both manned and unmanned aviators. Participants provided categorical information about themselves to include age, sex, profession, experience in aviation, and experience in unmanned aviation. This information allowed for a better understanding of the study population.

Validation and Reliability

Validation of the survey occurred through a series pilot surveys to eliminate systematic or contextual confusions. After the pilot surveys, careful consideration was given to feedback and if deemed applicable, altered specific aspects of the original survey.

Only data from participants that completed the entire survey was to the final analysis.

Proposed Data Analysis

Data collected from the survey was processed using IBM SPSS® Statistics Software. Information from each demographic may correlate with different approaches to risk assessment. Descriptive data and significance testing provided sufficient data to use in the discussion.

Protection of Participants

All data provided from survey participants were cleared of any personally identifiable information. These measures were integral for promoting complete and honest responses from survey participants.

CHAPTER IV

RESULTS

Demographics

There were eighty-seven (of eighty-nine) responses received during the collection period which met the completion threshold. Therefore the two incomplete responses were discarded.

Unmanned v. Manned

The population consisted of two major subgroups. Of the eighty-seven complete responses twenty-seven (31.0 percent) identified as UAS focused and the remaining sixty (69.0 percent) identified as traditionally manned aviators (Figure 1).

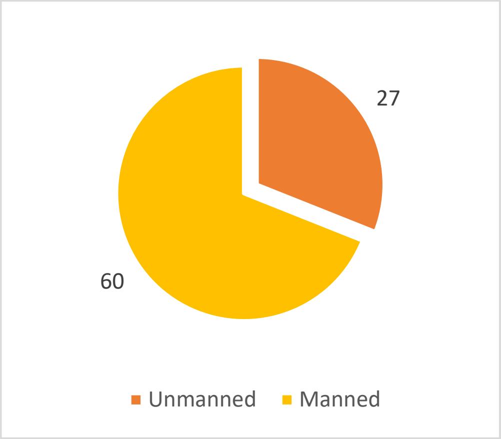


Figure 1 Unmanned v. Manned Participants.

Age

Age was reported by eighty-two participants of the total population. Of those eighty-two, twenty-five belonged to the group of unmanned participants, and fifty-seven belonged to the manned pilot population. The ages were broken down into categories, and participants' responses were recorded into their respective group. Those categories being eighteen to twenty-four, twenty-five to thirty-four, thirty-six to forty-four, and forty-five and older. The majority of unmanned participants, forty percent, fell in the twenty-five to thirty-four age group whereas the majority of manned pilots, eighty-one percent fell into the eighteen to twenty-four age group (Table 1).

Table 1. *Age of Participants.*

Variable		Unmanned	Manned	Total
What is your age?	18-24	6	46	52
	25-34	10	4	14
	36-44	7	7	14
	45+	2	0	2

Gender

Of the total population seventy-eight (89.7 percent), were male and nine (10.3 percent) reported as female. The UAS population reported twenty-six (96.3 percent) male and one (3.7 percent) female. Manned aviation reported fifty-two (86.7 percent) male and 8 (13.3 percent) female (Table 2.).

Table 2. *Gender of Participants.*

Variable		Unmanned	Manned	Total
What is your gender?	Male	26	52	78
	Female	1	8	9

Level of Education

Twenty-six unmanned and fifty-nine manned participants provided their level of education. The majority of UAS participants, eleven (42.3 percent), possessed a four-year college degree. In comparison, the majority of manned participants, thirty-nine (66 percent), indicated they had received some level of college education (Table 3).

Table 3. *Level of Education*

Variable		Unmanned	Manned	Total
What is your highest level of education?	High school graduate	2	7	9
	Some college	3	39	42
	two-year degree	1	2	3
	four-year degree	11	6	17
	Professional degree	9	4	13
	Doctorate	0	1	1

Military Service

Of the eighty-seven participants, fifteen (17.2 percent) indicated they currently serve, or previously served as a member of the United States Military. Nine (60.0 percent) of those participants were UAS, and six (40.0 percent) were from the manned population (Table 4). The most populous group, five (55.0 percent), of the unmanned participants connected to the Military, served in the United States Army while the largest group, three (50.0 percent), of all manned participants, served in the United States Marines (Figure 2).

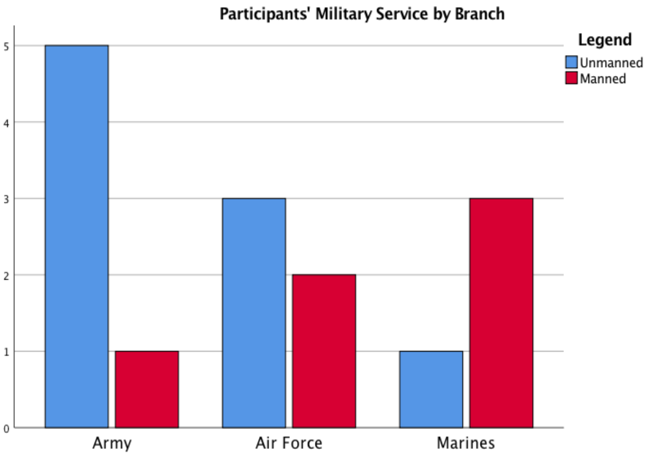


Figure 2. Participant's military service by branch.

Table 4. *Participants with Current or Former Military Service.*

Variable		Unmanned	Manned	Total
Have you served in the U.S Military?	Yes	9	6	15
	No	18	55	72

Manned Pilot Experience

Manned aviation experience was reported by twenty-two of twenty-seven (81.5 percent) UAS respondents. They possessed two student pilot certificates, seven private pilot certificates, and thirteen commercial pilot certificates. Of those, four indicated that they were Certified Flight Instructors. Twenty respondents provided estimated hours operating manned aircraft. The most extensive group (n=13) of UAS operators reported having between one hundred one and five hundred flight hours, with two operators indicating experience of greater than two-thousand hours.

In comparison, two manned aviators held no certificates, eight held student pilot certificates, twenty-seven held private pilot certificates, twenty held commercial pilot certificates, and four held Airline Transport Pilot certificates. About half of the manned aviation respondents had less than 100 hours total time, with four reporting greater than two-thousand hours (Table 5).

Table 5. Hours Piloting Manned Aircraft (UAS & Manned).

Variable		Unmanned	Manned	Total
Indicate number of hours piloting manned aircraft.	Less than 100	3	28	31
	101-500	13	24	37
	501-1000	2	4	6
	1001-2000	0	1	1
	Greater than 2000	2	4	6

Unmanned Aircraft Operating Experience

Unmanned aircraft operating experience was reported by twenty-six unmanned, and twenty-five manned respondents reported having some experience operating unmanned aircraft systems.

Experience among unmanned participants varied with nine (34.6 percent) indicating less than one hundred hours of operating experience and six (23.1 percent) reporting having greater than two thousand hours of operating experience (Figure 3). When asked to identify their current occupation as it relates to UAS operations the top three selections were program management (n=7), commercial operations (n=5), and hobbyist (n=5) (Table 6).

Over ninety percent of manned participants with some level of UAS experience indicated having less than one hundred hours of experience. The remaining participants indicated their operating time between one hundred one and five hundred hours (Figure 3). A majority of the thirty-five manned aviators with occupations related to UAS, sixty-six percent (n=23), designated their operations as only hobbyist level (Table 6).

Table 6. Current Occupation as it Relates to UAS.

Variable	Unmanned	Manned	Total
Hobbyist	5	23	28
Commercial Operator	5	7	12
Military	2	1	3
Program Management	7	0	7
Engineering	1	0	1
Other	6	4	10

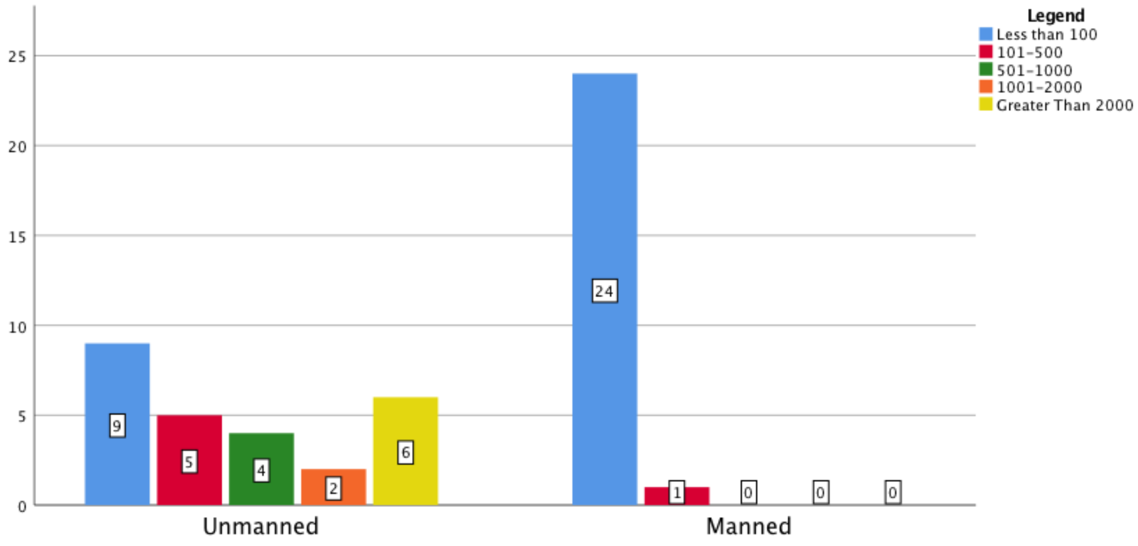


Figure 3. Hours Operating Unmanned Aircraft (UAS & Manned)

Survey Data Analysis

As stated above, eighty-nine responses were collected using Qualtrics© Survey tool. However, two responses were omitted from the data analysis due to incomplete answers. Analysis of the data with and without the two omitted responses showed that they did not affect the significance of the study.

The following analysis breaks down the survey items into three sections. These sections correspond to the research questions presented in chapter one of this study.

Cronbach's Alphas

Each section was tested for reliability and consistency of responses. The safety perception subscale consisted of nine items with an α=.48, below the acceptable value of .70. Further testing in SPSS revealed no change to the Cronbach's Alpha by removing any individual item. The risk perception subscale consisted of nine items with an α=.88

meeting the required level of reliability. The organization safety culture subscale consisted of eleven items with an α=.82 meeting the required level of reliability.

Method of Analysis

Collected responses for each research questions were analyzed in two ways. The first method looked at the entire data set as one result, indicating each participant's mean rating for the section. The second method analyzed each variable. Both methods compared the groups "manned" and unmanned."

Research Question 1: How does the perspective of safety differ between the manned and unmanned aviation industries?

Descriptive

The participants' perception of safety was evaluated based on their responses to nine survey items. Each of these items was presented in Likert type statements in which the participant selected to which degree they either agreed or disagreed with the statements.

Items identified as "5.X" ranged from "strongly agree" to "strongly disagree." "agree," "neutral," and "disagree," made up the three middle selections. Items identified as "6.X" ranged from "always" to "never." "Most of the time," "about half the time," and "sometimes," completed middle selections. A "not applicable" option was available for participants. When selected, "not applicable" options were treated as missing responses. Survey items for the first research question had an average 91.2 percent response rate (Table 7).

Table 7. Research question one survey details.

Survey Item Identifier	Response Rate	Survey Item Detail
5.5	97.7 percent	Your organization provides adequate training for emergency situations to all parties involved in flight operations.
5.6	97.7 percent	Your training included specific instruction on recognizing adverse meteorological or atmospheric conditions.
5.8	96.6 percent	As a PIC, you maintain a sterile cockpit, limiting non-essential communication, during critical phases of flight.
6.1	96.6 percent	The pilot or operator in command always conducts a walk around.
6.3	78.2 percent	Intentionally crashing an aircraft to ensure the flight objective is met is acceptable.
6.4	98.9 percent	Cutting corners in regards to SOPs is acceptable if it will help you meet your mission objectives faster as long as there is no blatant disregard for safety.
6.6	98.9 percent	As the PIC, you feel personally responsible for the outcome of the flight.
6.7	94.3 percent	During prolonged or extended flight operations, you find it difficult to maintain complete concentration on the task at hand.
6.8	62.1 percent	When a flight operation extends beyond a single PIC's duty period, the incoming crew is always provided with a detailed brief on the current status of the operation, including aircraft configuration/status and any noteworthy flight events.

Method One – Survey Items Combined with Mean Score

Items 6.3, 6.4, and 6.8 were re-coded to reverse their responses to create a standardized set of data. After the re-coding, low scores represented high safety perception or awareness, and high scores represented low safety perception or awareness.

After creating a uniform scale, a Mean Safety Perception Rating (MSPR) was calculated for each participant using the compute variable function of SPSS.

Normality Testing

The MSPR was tested for normality (Figure 4). Based on the histogram depicting sizeable positive skewness, it was determined that the MSPR results were not normally distributed. A reciprocal (1/X) transformation was used to reduce the skewness and bring the results closer to normality. The resulting histogram showed relatively normal distributions (Figure 5).

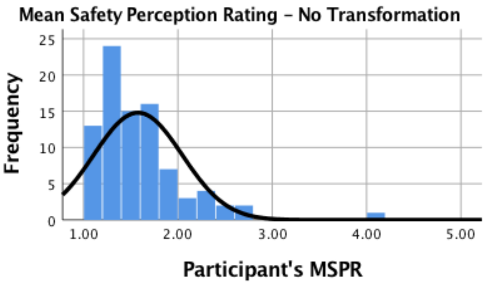


Figure 4. MSPR without transformation.

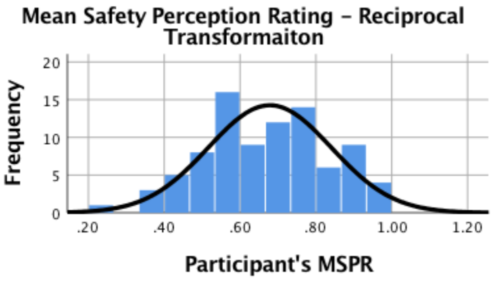


Figure 5. MSPR after Reciprocal Transformation

One Way Analysis of Variance

Having achieved a more acceptable level of normality after the reciprocal transformation, a one-way ANOVA was conducted for the MSPR. The main effect of whether participants identified as unmanned or manned was not significant at the p<.05 level [F (1,86) =.854, p=.358]. Perception of safety did not differ between manned (*M = .67, SD = .15)* and unmanned (*M = .70, SD = .18)* groups.

Method Two – Individual Variable Analysis

The second method of data analysis did not correct for normality; instead, non-parametric testing was used to assess relationships. Each of the 9 survey items was analyzed individually with general descriptive statistics followed by the Mann-Whitney independent samples test.

5.5 Your organization provides adequate training for emergency situations to all parties involved in flight operations.

Descriptive Statistics

Responses to the statement “your organization provides adequate training for emergency situations to all parties involved in flight operations” were received from twenty-six (96.2 percent) unmanned participants and fifty-nine (98.3 percent) manned participants. Both groups, unmanned (*M* = *1.58, SD 1.07)* and manned (*M* = *1.49, SD* = *.858),* largely agreed with the statement; indicating a high level of safety perception (Figures 6 and 7).

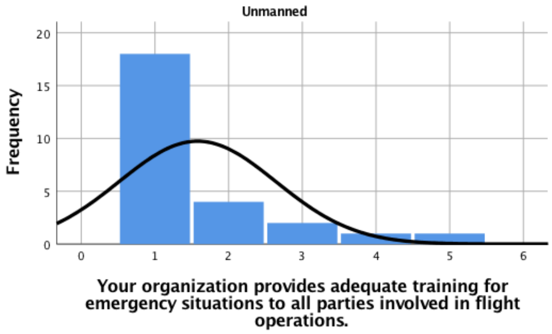


Figure 6. Histogram of 5.5 Unmanned.

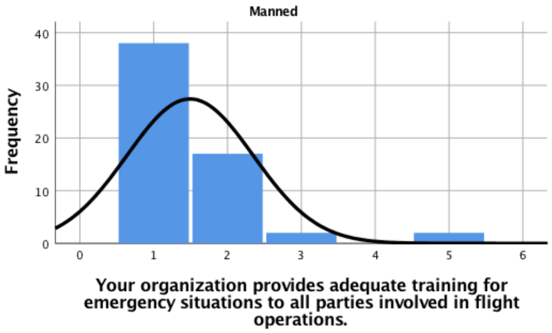


Figure 7. Histogram of 5.5 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents selected “low risk” answers and no statistically significant differences existed between groups (*U = 755, P = .89).* Therefore, the null hypothesis cannot be rejected.

5.6 Your training included specific instruction on recognizing adverse meteorological or atmospheric conditions.

Descriptive Statistics

Responses to the statement “your training included specific instruction on recognizing adverse meteorological or atmospheric conditions” were received from twenty-six (96.2 percent) of the unmanned participants and fifty-nine (98.3 percent) of the manned participants. Both groups, unmanned (*M = 1.46, SD .761)* and manned (*M = 1.37, SD = .667),* largely agreed with the statement; indicating a high level of safety perception (Figures 8 and 9).

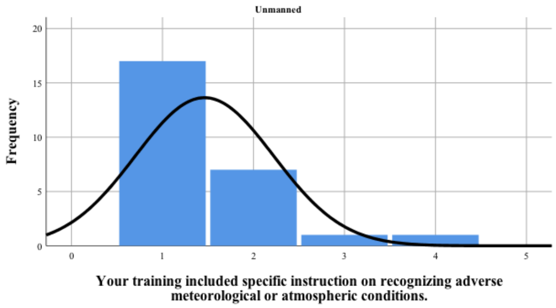


Figure 8. Histogram of 5.6 Unmanned

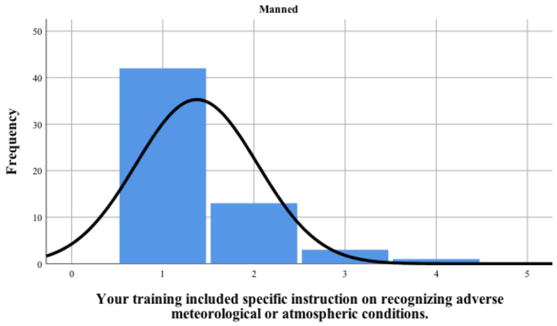


Figure 9. Histogram of 5.6 Manned

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents selected “low risk” answers and no statistically significant differences existed between groups (*U = 722.50, P = .60).* Therefore, the null hypothesis cannot be rejected.

5.8 As a PIC, you maintain a sterile cockpit, limiting non-essential communication, during critical phases of flight.

Descriptive Statistics

Responses to the statement “as a PIC, you maintain a sterile cockpit, limiting non-essential communication, during critical phases of flight” were received from twenty-four (88.9 percent) of the unmanned participants and sixty (100.0 percent) of the manned participants. Both groups, unmanned (*M = 1.38, SD = .77)* and manned (*M = 1.52, SD = .65),* largely agreed with the statement; indicating a high level of safety perception (Figures 10 and 11).

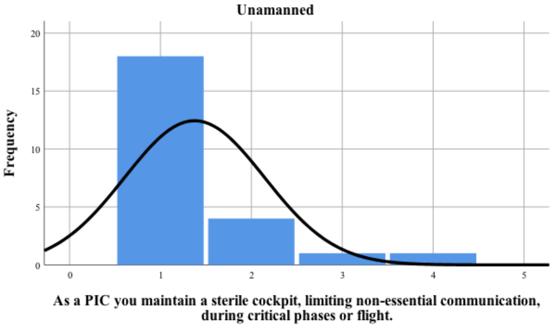


Figure 10. Histogram of 5.8 Unmanned.

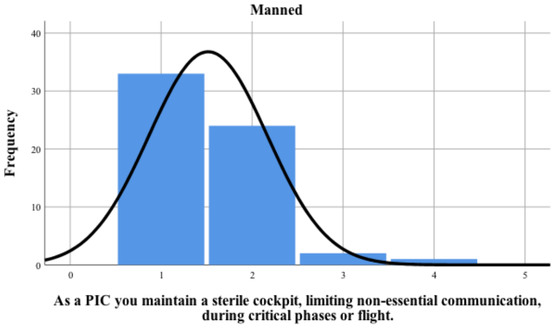


Figure 11. Histogram of 5.8 Manned

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents selected “low risk” answers. UAS respondents had a slightly lower mean rank (37.27) in comparison to the mean rank of the manned participants (44.59). However, no statistically significant differences existed between groups (*U = 594.50, P = .15).* Therefore, the null hypothesis cannot be rejected based on this statement.

6.1 The pilot or operator in command always conducts a walk around.

Descriptive Statistics

Responses to the statement “the pilot or operator in command always conducts a walk around” were collected from twenty-six (96.2 percent) of the unmanned participants and fifty-eight (96.7 percent) of the manned participants. Both groups, unmanned (*M = 1.08, SD = .272)* and manned (*M = 1.17, SD = .50),* largely agreed with the statement; indicating a high level of safety perception (Figures 12 and 13).

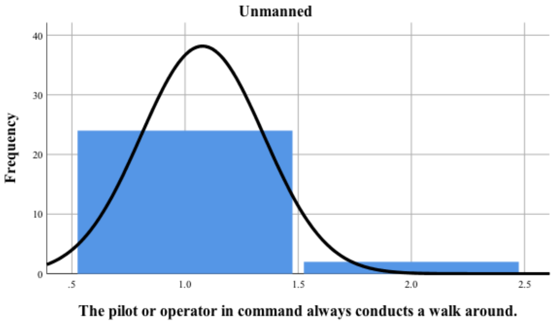


Figure 12. Histogram of 6.1 Unmanned.

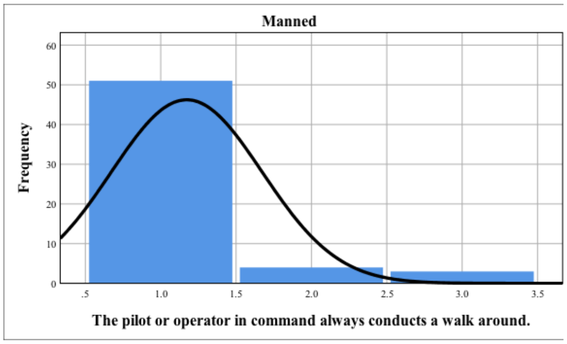


Figure 13. Histogram of 6.1 Manned

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents selected “low risk” answers and no statistically significant differences existed between groups (*U = 718.00, P = .516).* Therefore, the null hypothesis cannot be rejected based on this statement.

6.3 Intentionally crashing an aircraft to ensure the flight objective is met is acceptable.

Descriptive Statistics

Responses to the statement “intentionally crashing an aircraft to ensure the flight objective is met is acceptable” were collected from twenty (74.1 percent) of the unmanned participants and forty-eight (80.0 percent) of the manned participants. Both groups, unmanned (*M = 1.65, SD = 1.09)* and manned (*M = 1.67, SD = 1.36)*, largely agreed with the statement; indicating a high level of safety perception (Figures 14 and 15).

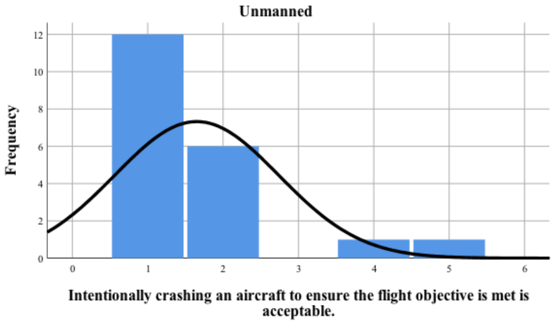


Figure 14. Histogram of 6.3 Unmanned.

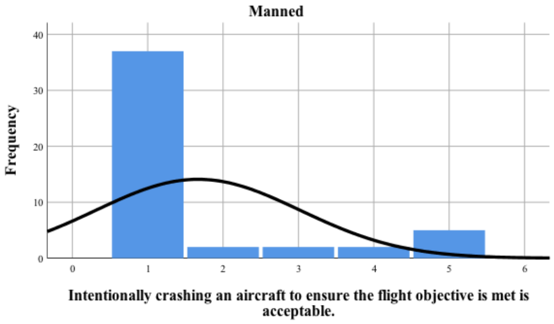


Figure 15. Histogram of 6.3 Manned.

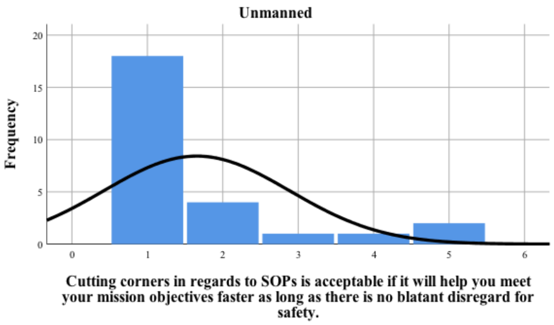
Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents selected “low risk” answers and no statistically significant differences existed between groups (*U = 422.50, P = .33).* Therefore, the null hypothesis cannot be rejected based on this statement.

6.4 Cutting corners in regards to SOPs is acceptable if it will help you meet your mission objectives faster as long as there is no blatant disregard for safety.

Descriptive Statistics

Responses to the statement “cutting corners in regards to SOPs is acceptable if it will help you meet your mission objectives faster as long as there is no blatant disregard for safety” were collected from twenty-six (96.2 percent) of the unmanned participants and sixty (100.0 percent) of the manned participants. Both groups, unmanned (*M = 1.65, SD = 1.23)* and manned (*M = 1.82, SD = 1.14)*, largely agreed with the statement; indicating a high level of safety perception (Figures 16 and 17).



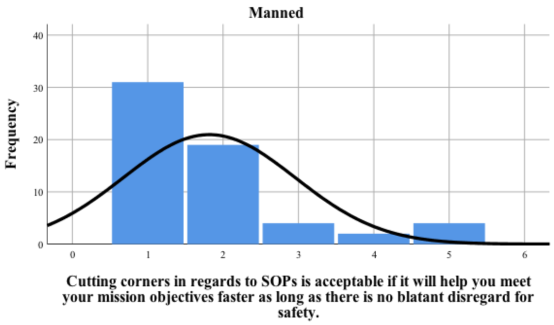


Figure 16. Histogram of 6.4 Unmanned. Figure 17. Histogram of 6.4 Manned

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents selected “low risk” answers and no statistically significant differences existed between groups (*U = 664.00, P = .22).* Therefore, the null hypothesis cannot be rejected based on this statement.

6.6 As the PIC, you feel personally responsible for the outcome of the flight.

Descriptive Statistics

Responses to the statement “as the PIC; you feel personally responsible for the outcome of the flight” were collected from twenty-six (96.2 percent) of the unmanned participants and sixty (100.0 percent) of the manned participants. Both groups, unmanned (*M = 1.12, SD = .33)* and manned (*M = 1.18, SD = .43)*, largely agreed with the statement; indicating a high level of safety perception (Figures 18 and 19).

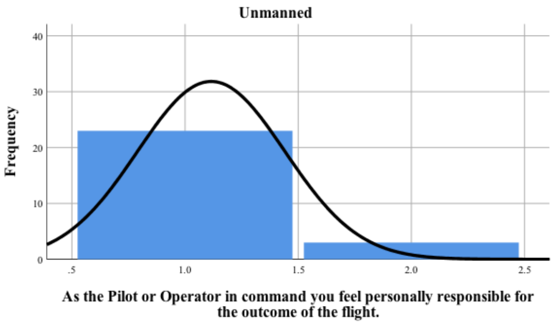


Figure 18. Histogram of 6.6 Unmanned.

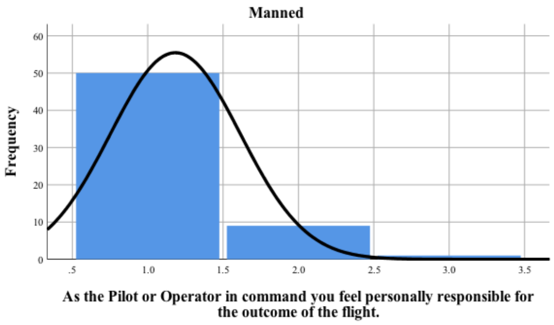


Figure 19. Histogram of 6.6 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents selected “low risk” answers and no statistically significant differences existed between groups (*U =738.50, P = .53).* Therefore, the null hypothesis cannot be rejected based on this statement.

6.7 During long or extended flight operations, you find it difficult to maintain complete concentration on the task at hand.

Descriptive Statistics

Responses to the statement “during long or extended flight operations, you find it difficult to maintain complete concentration on the task at hand” were collected from twenty-four (88.9 percent) of the unmanned participants and Fifty-eight (96.7 percent) of the manned participants. Both groups, unmanned (*M = 2.25, SD = .85)* and manned (*M = 2.31, SD = .96),* largely agreed with the statement; indicating a high level of safety perception (Figures 20 and 21).

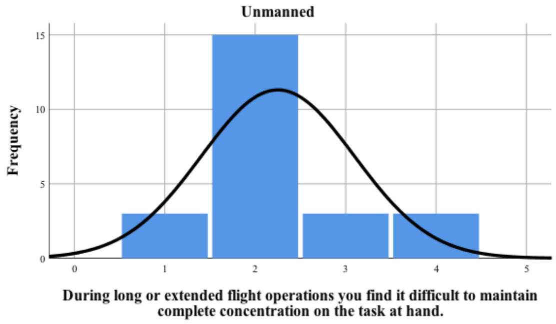


Figure 20. Histogram of 6.7 Unmanned.

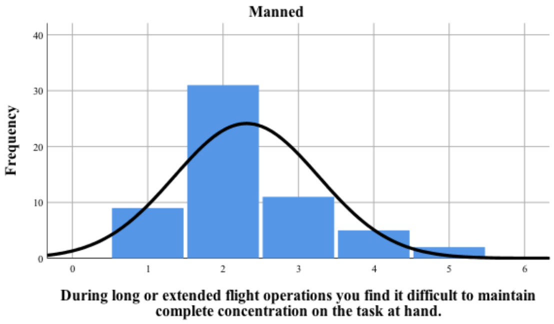


Figure 21. Histogram of 6.7 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents selected “low risk” answers and no statistically significant differences existed between groups (*U =678.00, P = .84).* Therefore, the null hypothesis cannot be rejected based on this statement.

6.8 When a flight operation extends beyond a single PIC’s duty period, the incoming crew is always provided with a detailed brief on the current status of the operation, including aircraft configuration/status and any noteworthy flight events.

Descriptive Statistics

Responses to the statement “when a flight operation extends beyond a single PIC’s duty period, the incoming crew is always provided with a detailed brief on the current status of the operation, including aircraft configuration/status and any noteworthy flight events” were collected from twenty-one (77.8 percent) of the unmanned participants and Thirty-three (55.0 percent) of the manned participants. Both groups, unmanned (*M = 1.38, SD = .50)* and manned (*M = 1.98, SD = 1.31),* largely agreed with the statement; indicating a high level of safety perception (Figures 22 and 23).

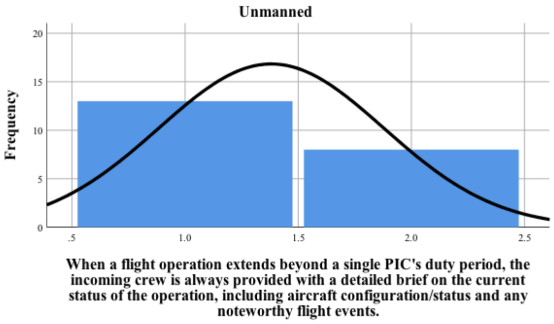


Figure 22. Histogram of 6.8 Unmanned.

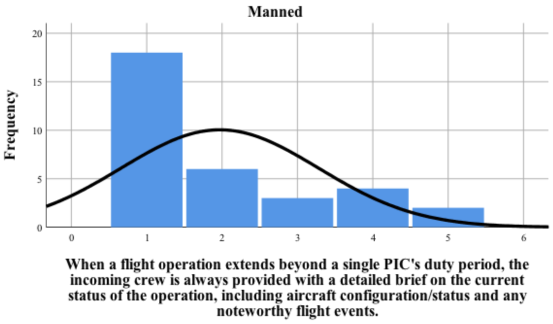


Figure 23. Histogram of 6.8 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents selected “low risk” answers and no statistically significant differences existed between groups (*U =285.00, P = .22).* Therefore, the null hypothesis cannot be rejected based on this statement.

Research Question 2: Does the potential for loss of life, or the lack thereof, affect the pilot or operator’s perception of risk?

Descriptive

The participant’s perception of risk was evaluated based on the following nine survey items. Each of these items was presented in ordinal rank statements asked the participant to rate risk in a given scenario. Participant’s answers ranged from no risk (0) to severe risk (10). Survey items for the first research question had an average 90.9 percent response rate (Table 8).

Table 8. Research question two survey details.

Survey Item Identifier	Response Rate	Survey Item
4.1	96.6 percent	Please rate the risk involved with a complete engine failure. (0-10)
4.2	90.8 percent	Please rate the risk involved with a complete engine failure on take-off or launch. (0-10)
4.3	85.1 percent	Please rate the risk involved with a complete electrical failure during flight operations. (0-10)
4.4	88.5 percent	Please rate the risk involved with an engine (or motor) fire during flight operations. (0-10)
4.5	88.5 percent	Please rate the risk involved with inadvertent flight into inclement weather. (0-10)
4.6	93.1 percent	Please rate the risk involved with losing radio communication with Air Traffic Control. (0-10)
4.7	95.4 percent	Please rate the risk involved with mid-air collisions. (0-10)
4.8	88.5 percent	Please rat the risk involved with flight in moderate or higher turbulence. (0-10)
4.9	92.0 percent	Please rate the risk involved with losing primary navigation systems (GPS, FMS, VOR, etc.) (0-10)

Method One – Survey Items Combined into Mean Score

No re-coding was necessary for data pertaining to research question two. All scores ranged from low to severe risk (0-10). The mean score for risk perception was found using the compute variable tool in SPSS and was used for statistical testing in method one. This provided a Mean Risk Perception Score (MRPS) for each participant.

Normality Testing

The MRPS was tested for normality (Figure 24). Based on the histogram depicting positive skewness, it was determined that the MRPS results were not normally distributed. A logarithmic (log10) transformation was used to reduce the skewness and bring the results closer to normality. The resulting histogram showed relatively normal distributions (Figure 25).

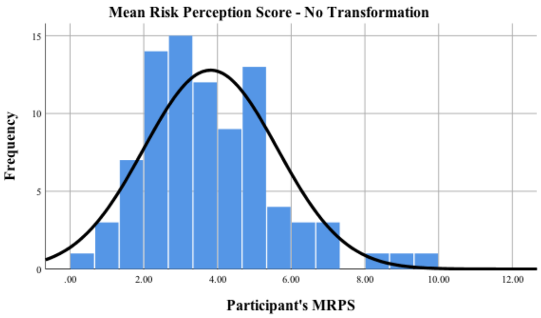


Figure 24. MRPS without transformation.

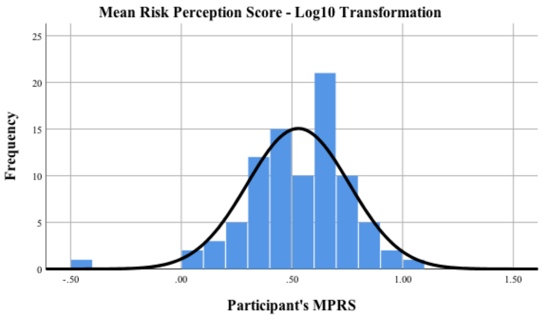


Figure 25. MPRS with Log10 Transformation.

One Way Analysis of Variance

Having achieved a more acceptable level of normality after the reciprocal transformation, a one-way ANOVA was conducted for the MRPS. The main effect of whether participants identified as unmanned or manned was not significant, [F (1,86) =.428, p=.515]. Perception of risk did not differ between manned (*M = .52, SD = .25)* and unmanned (*M = .55, SD = .19)* groups.

Method Two – Individual Variable Analysis

The second method of data analysis did not correct for normality; rather it utilized non-parametric testing to assess relationships. Each of the 9 survey items was analyzed individually with general descriptive statistics followed by the Mann-Whitney independent samples test.

4.1 Please rate the risk involved with a complete engine failure. (0-10)

Descriptive Statistics

Responses to the statement "please rate the risk involved with a complete engine failure" were collected from twenty-six (96.2 percent) of the unmanned participants and fifty-eight (96.7 percent) of the manned participants. Both groups, unmanned (*M = 2.62, SD = 1.94)* and manned (*M = 3.45, SD = 2.58)*, indicated a low to moderate level of risk (Figures 26 and 27).

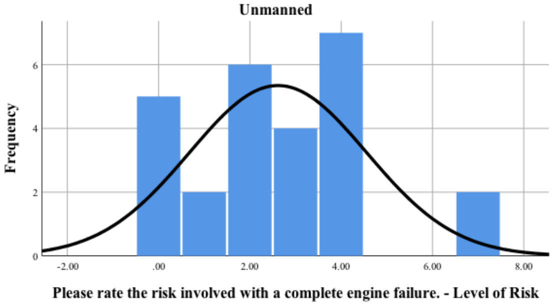


Figure 26. Histogram of 4.1 Unmanned.

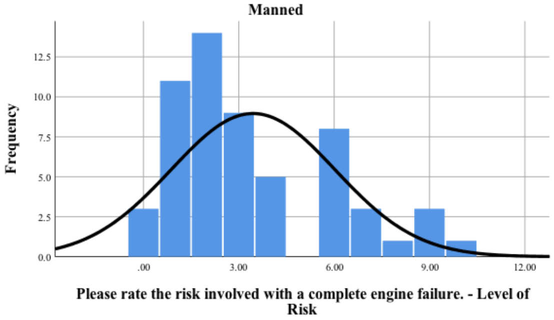


Figure 27. Histogram of 4.1 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents indicated low risk given the scenario. However, no statistically significant differences existed between groups (*U =660.00, P = .36).* Therefore, the null hypothesis cannot be rejected based on this statement.

4.2 Please rate the risk involved with a complete engine failure on take-off or launch. (0-10)

Descriptive Statistics

Responses to the statement “please rate the risk involved with a complete engine failure on take-off or launch” were collected from twenty-three (85.2 percent) of the unmanned participants and fifty-six (93.3 percent) of the manned participants. Both groups, unmanned (*M = 2.26, SD = 2.68)* and manned (*M = 3.09, SD = 2.89),* indicated a low to moderate level of risk (Figures 28 and 29).

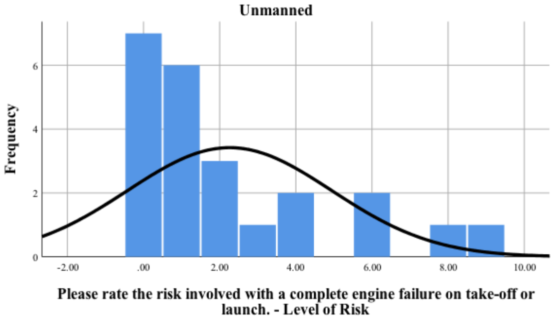


Figure 28. Histogram of 4.2 Unmanned.

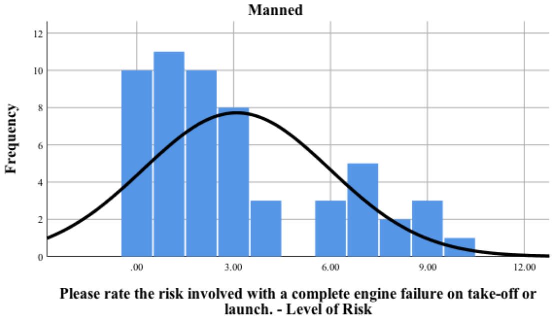


Figure 29. Histogram of 4.2 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents indicated low risk given the scenario. However, no statistically significant differences existed between groups (*U =513.50, P = .15).* Therefore, the null hypothesis cannot be rejected based on this statement.

4.3 Please rate the risk involved with a complete electrical failure during flight operations. (0-10)

Descriptive Statistics

Responses to the statement “please rate the risk involved with a complete electrical failure during flight operations” were collected from twenty-two (81.5 percent) of the unmanned participants and fifty-two (86.7 percent) of the manned participants. Both groups, unmanned ($M = 2.82$, $SD = 2.61$) and manned ($M = 4.00$, $SD = 2.77$), indicated a low to moderate level of risk (Figures 30 and 31).

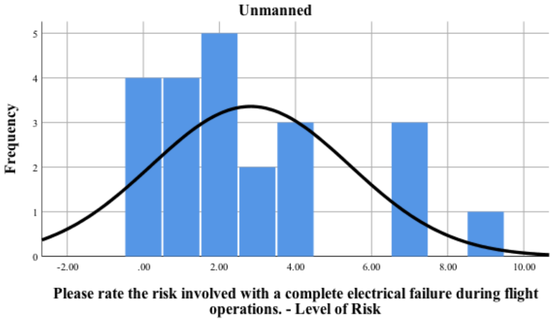


Figure 30. Histogram of 4.3 Unmanned.

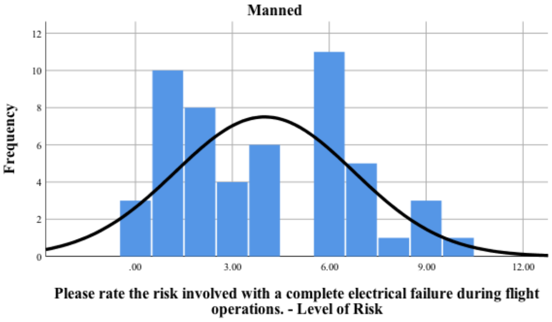


Figure 31. Histogram of 4.3 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents indicated low to medium risk given the scenario, however, no statistically significant differences existed between groups ($U = 436.00$, $P = .10$). Therefore, the null hypothesis cannot be rejected based on this statement.

4.4 Please rate the risk involved with an engine (or motor) fire during flight operations. (0-10)

Descriptive Statistics

Responses to the statement “please rate the risk involved with an engine (or motor) fire during flight operations” were collected from twenty-two (81.5 percent) of the unmanned participants and fifty-five (91.7 percent) of the manned participants. Both groups, unmanned (*M* = *2.32, SD* = *2.57)* and manned (*M* = *2.25, SD* = *2.79)*, indicated a low to moderate level of risk (Figures 22 and 23).

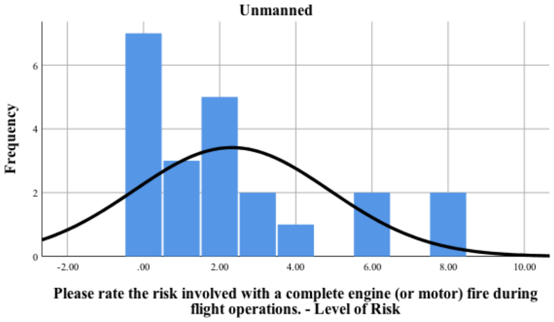


Figure 32. Histogram of 4.4 Unmanned.

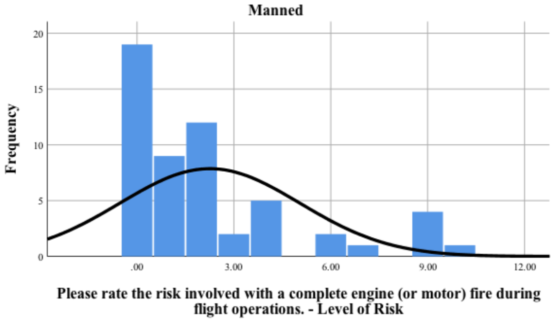


Figure 33. Histogram of 4.4 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents indicated low risk given the scenario. However, no statistically significant differences exist between groups (*U* =*580.50, P* = *.78).* Therefore, the null hypothesis cannot be rejected based on this statement.

4.5 Please rate the risk involved with inadvertent flight into inclement weather. (0-10)

Descriptive Statistics

Responses to the statement "please rate the risk involved with inadvertent flight into inclement weather" were collected from twenty-three (85.2 percent) of the unmanned participants and fifty-four (90.0 percent) of the manned participants. Both groups, unmanned (*M = 5.13, SD = 2.75)* and manned (*M = 3.41, SD = 2.27),* indicated a moderate level of risk (Figures 34 and 35).

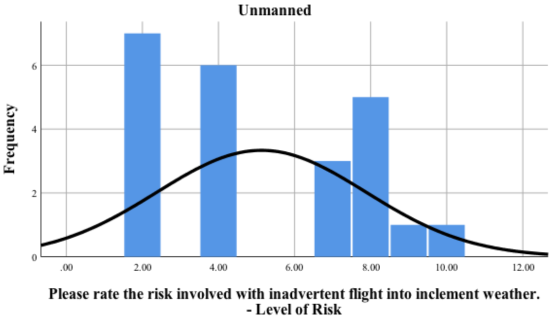


Figure 34. Histogram of 4.5 Unmanned.

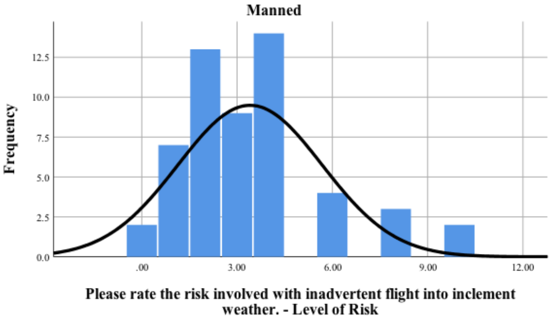


Figure 35. Histogram of 4.5 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that statistically significant differences exist between groups (*U =401.00, P = .01).*

4.6 Please rate the risk involved with losing radio communication with Air Traffic Control. (0-10)

Descriptive Statistics

Responses to the statement “please rate the risk involved with losing radio communication with Air Traffic Control” were collected from twenty-six (96.3 percent) of the unmanned participants and fifty-five (91.7 percent) of the manned participants. Both groups, unmanned (*M* = *5.69, SD* = *2.59)* and manned (*M* = *5.31*, *SD* = *2.12),* indicated a moderate level of risk (Figures 36 and 37).

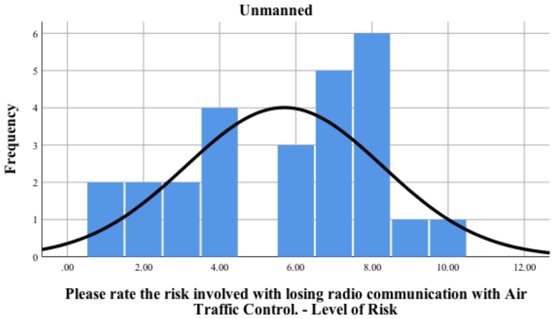


Figure 36. Histogram of 4.6 Unmanned.

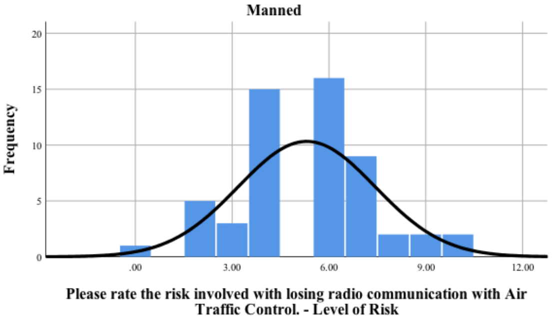


Figure 37. Histogram of 4.6 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both UAS and Manned respondents indicated moderate risk given the scenario. However, no statistically significant differences exist between groups (*U =615.50, P* = *.31).* Therefore, the null hypothesis cannot be rejected based on this statement.

4.7 Please rate the risk involved with mid-air collisions. (0-10)

Descriptive Statistics

Responses to the statement “please rate the risk involved with mid-air collisions” were collected from twenty-five (92.6 percent) of the unmanned participants and fifty-eight (96.7 percent) of the manned participants. Both groups, unmanned (*M = 4.04, SD = 3.48)* and manned (*M = 2.79, SD = 2.88),* indicated a low to moderate level of risk (Figures 38 and 39).

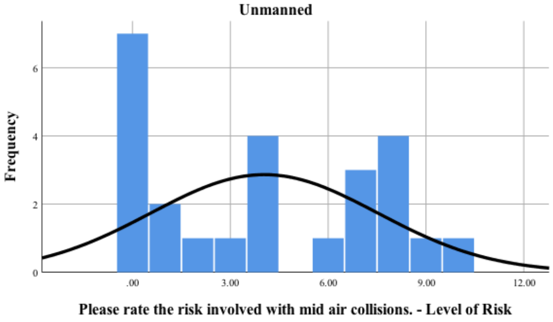


Figure 38. Histogram of 4.7 Unmanned.

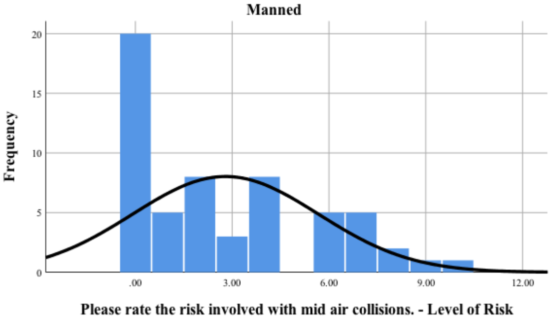


Figure 39. Histogram of 4.7 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that while both UAS and Manned respondents indicated low to moderate risk given the scenario, however, no statistically significant differences exist between groups (*U =576.50, P = .13).* Therefore, the null hypothesis cannot be rejected based on this statement.

4.8 Please rate the risk involved with flight in moderate or higher turbulence. (0-10)

Descriptive Statistics

Responses to the statement “please rate the risk involved with flight in moderate or higher turbulence” were collected from twenty-two (81.2 percent) of the unmanned participants and Fifty-five (91.7 percent) of the manned participants. Both groups, unmanned (*M = 4.82, SD = 2.36)* and manned (*M = 4.38, SD = 2.11),* indicated a moderate level of risk (Figures 40 and 41).

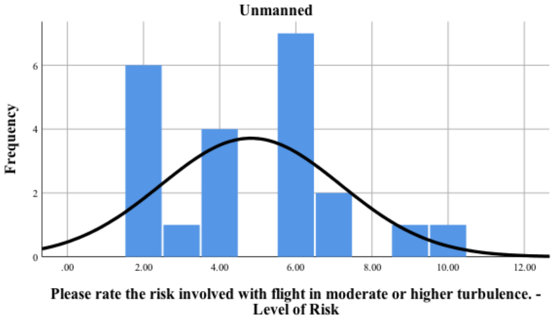


Figure 40. Histogram of 4.8 Unmanned.

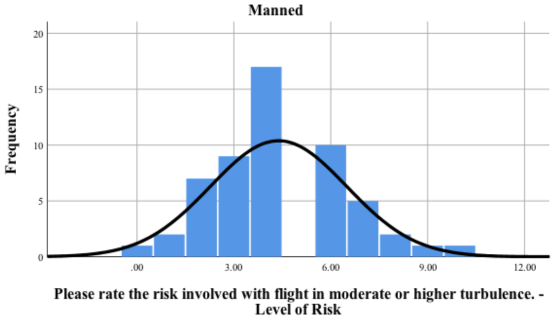


Figure 41. Histogram of 4.8 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that while both UAS and Manned respondents indicated moderate risk given the scenario, however, no statistically significant differences exist between groups (*U =554.50, P = .56).* Therefore, the null hypothesis cannot be rejected based on this statement.

4.9 Please rate the risk involved with losing primary navigation systems (GPS, FMS, VOR, etc.) (0-10)

Descriptive Statistics

Responses to the statement “please rate the risk involved with losing primary navigation systems (GPS, FMS, VOR, etc.)” were collected from twenty-six (96.3 percent) of the unmanned participants and Fifty-four (90.0 percent) of the manned participants. Both groups, unmanned (*M = 5.31, SD = 2.83)* and manned (*M = 5.91, SD = 2.51)*, indicated a moderate level of risk (Figures 42 and 43).

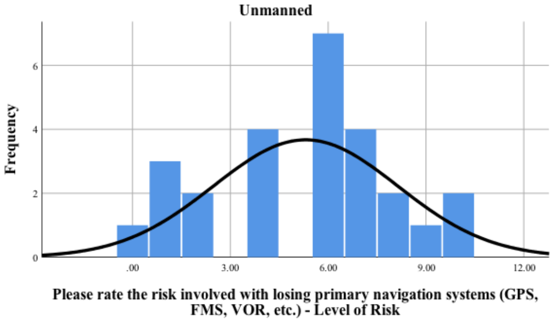


Figure 42. Histogram of 4.9 Unmanned.

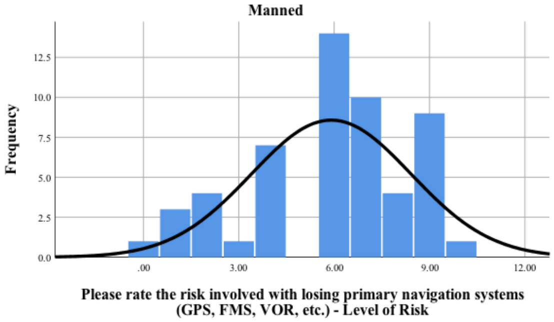


Figure 43. Histogram of 4.9 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that while both UAS and Manned respondents indicated moderate risk given the scenario, however, no statistically significant differences exist between groups (*U =610.50, P = .34).* Therefore, the null hypothesis cannot be rejected based on this statement.

Research Question 3: Is there a noticeable difference in safety culture when comparing manned and unmanned organizations?

Descriptive

The participants' responses to the following eleven survey items were used to evaluate differences in unmanned and manned organizational safety culture. Each of these items was presented in Likert type statements. Items identified as "5.X" ranged from "strongly agree" to "strongly disagree." "agree," "neutral," and "disagree," made up the three middle selections. Items identified as "6.X" ranged from "always" to "never." "Most of the time," "about half the time," and "sometimes," completed middle selections. A "not applicable" option was available for participants. When selected, "not applicable" options were treated as missing responses. Survey items for the third research question had a 97.2 percent response rate (Table 9).

Table 9. Research Question Three Survey Items.

Survey Item Identifier	Response Rate	Survey Item
5.1	100 percent	Your organization readily plans for emergency situations.
5.2	98.9 percent	Your organization promotes prompt reporting of any emergency or safety concerns or issues.
5.3	97.7 percent	Part of your flight planning includes planning for contingency or emergency situations. i.e., alternate airports, lost communications, etc.
5.4	95.4 percent	Your organization provides a plan for responding to an emergency landing off airport.
5.7	98.9 percent	Your training included a section on aircraft systems. Enough for you to be able to troubleshoot minor systems related issues independently.

Table 9. cont.

Survey Item Identifier	Response Rate	Survey Item
5.9	94.3 percent	As the PIC of a completed flight, you are responsible for writing up any known discrepancies that occurred before, during, or after your flight.
5.10	96.6 percent	Your training included sufficient instruction of the requirements of operating in the national airspace system per the Federal Aviation Administrations. To the extent that you, as the PIC, can reteach another of your peers.
6.2	97.7 percent	Your organization produces and adheres to a strict set of Standard Operating Procedures (SOPs).
6.5	97.7 percent	Your organization values safety over mission success.
6.9	96.6 percent	Your organization is proactive, rather than reactive, in developing safety standards and initiatives.
6.10	95.4 percent	Safety standards are well distributed to your entire organization to include, pilots, maintenance personnel, operations, etc.

Method One – Survey Items Combined into Mean Score

In order to standardize the responses so that scores one through five correlated with increasing safety concerns, items 6.9 and 6.10 were re-coded to the inverse of the original data. Once standardized, the survey items were computed via the compute variables function to provide the mean safety culture score (MSCS).

Normality Testing

The MSCS was then tested for normality (Figure 44). Based on the histogram depicting positive skewness, it was determined that the MSCS results were not normally distributed. Transformations were attempted; however, normality could not be achieved to a relatively acceptable level (Figures 45, 46, and 47). Therefore, no further parametric statistics were analyzed.

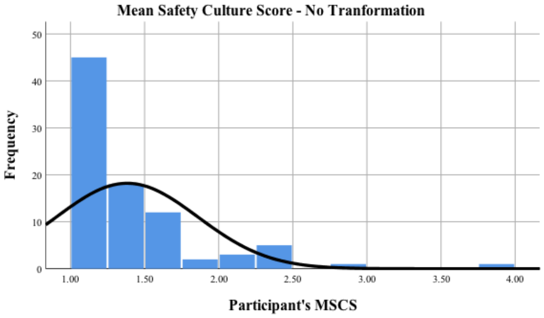


Figure 44. MSCS no Transformation.

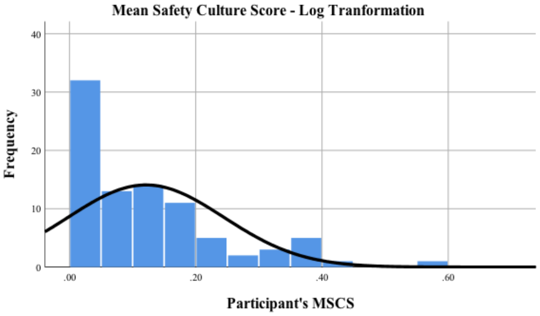


Figure 45. MSCS Log10 Transformation.

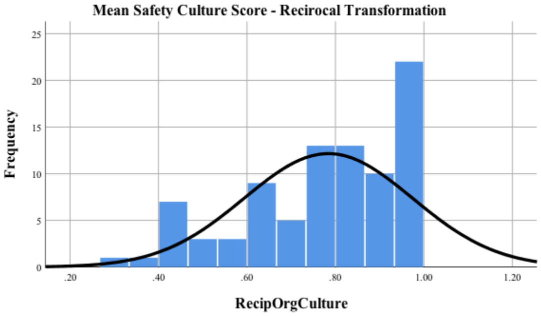


Figure 46. MSCS Reciprocal Transformation.

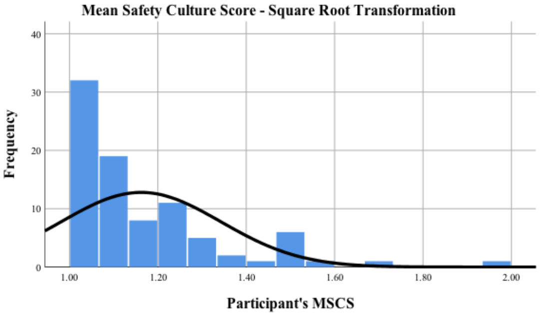


Figure 47. MSCS Sqrt. Transformation.

Method Two – Individual Variable Analysis

The second method of data analysis did not correct for normality; instead it utilized non-parametric testing to assess relationships. Each of the 11 survey items was analyzed individually with general descriptive statistics followed by the Mann-Whitney independent samples test.

5.1 Your organization readily plans for emergency situations.

Descriptive Statistics

Responses to the statement “your organization readily plans for emergency situations” were collected from twenty-seven (100.0 percent) of the unmanned participants and Sixty (100.0 percent) of the manned participants. Both groups, unmanned (*M = 1.48, SD = .89)* and manned (*M = 1.20, SD = .40)*, agreed with the statement; indicating a low safety concern in their organization (Figures 48 and 49).

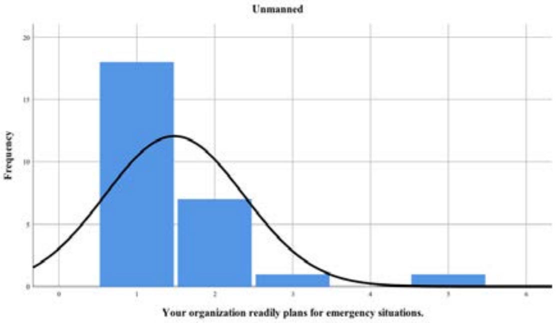


Figure 48. Histogram of 5.1 Unmanned.

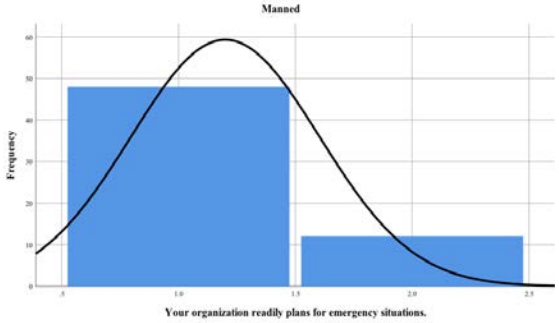


Figure 49. Histogram of 5.1 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both groups agreed with the statement and no statistically significant differences exist between groups (*U =690.00, P = .14).* Therefore, the null hypothesis cannot be rejected based on this statement.

5.2 Your organization promotes prompt reporting of any emergency or safety concerns or issues.

Descriptive Statistics

Responses to the statement “your organization promotes prompt reporting of any emergency or safety concerns or issues” were collected from twenty-seven (100.0 percent) of the unmanned participants and fifty-nine (98.3 percent) of the manned participants responded. Both groups, unmanned (*M = 1.48, SD = .98)* and manned (*M = 1.22, SD = .67)*, agreed with the statement; indicating a low safety concern in their organization (Figures 50 and 51).

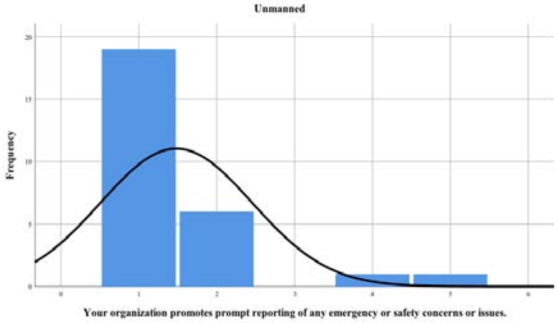


Figure 50. Histogram of 5.2 Unmanned.

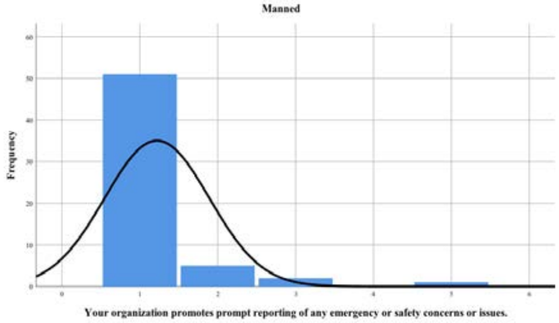


Figure 51. Histogram of 5.2 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both groups agreed with the statement and no statistically significant differences exist between groups (*U =671.00, P = .09).* Therefore, the null hypothesis cannot be rejected based on this statement.

5.3 Part of your flight planning includes planning for contingency or emergency situations. i.e., alternate airports, lost communications, etc.

Descriptive Statistics

Responses to the statement “part of your flight planning includes planning for contingency or emergency situations. i.e., alternate airports, lost communications, etc.” were collected from twenty-five (92.6 percent) of the unmanned participants and sixty (100.0 percent) of the manned participants. Both groups, unmanned (*M = 1.40, SD = .91)* and manned (*M = 1.18, SD = .39)*, agreed with the statement; indicating a low safety concern in their organization (Figures 52 and 53).

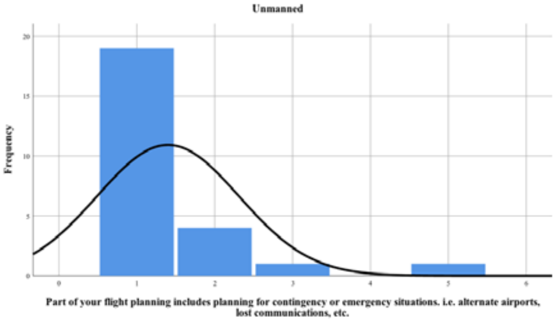


Figure 52. Histogram of 5.3 Unmanned.

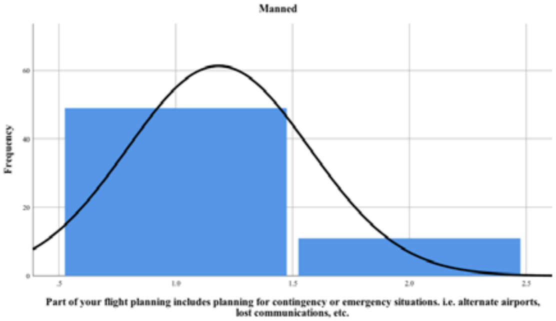


Figure 53. Histogram of 5.3 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both groups agreed with the statement and no statistically significant differences exist between groups (*U =696.50, P = .46).* Therefore, the null hypothesis cannot be rejected based on this statement.

5.4 Your organization provides a plan for responding to an emergency landing off airport.

Descriptive Statistics

Responses to the statement “your organization provides a plan for responding to an emergency landing off-airport” were collected from twenty-four (88.9 percent) of the unmanned participants and fifty-nine (98.3 percent) of the manned participants. Both groups, unmanned (*M = 1.79, SD = 1.22)* and manned (*M = 1.49, SD = .77),* agreed with the statement; indicating a low safety concern in their organization (Figures 54 and 55).

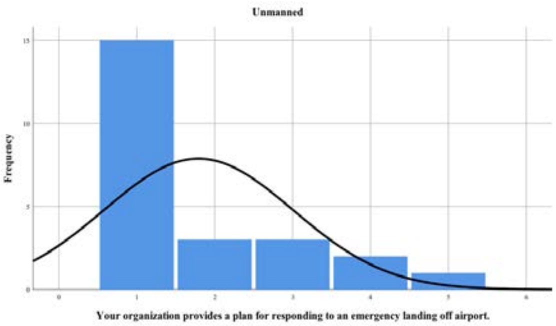


Figure 54. Histogram of 5.4 Unmanned.

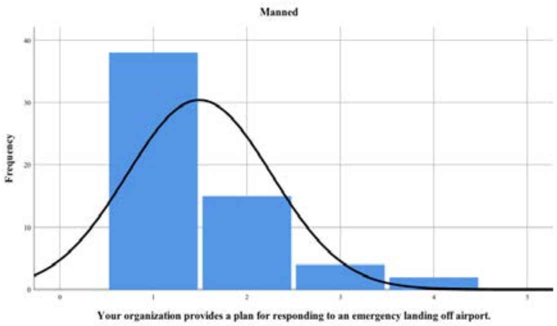


Figure 55. Histogram of 5.4 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both groups agreed with the statement and no statistically significant differences exist between groups (*U =654.50, P = .53).* Therefore, the null hypothesis cannot be rejected based on this statement.

5.7 Your training included a section on aircraft systems. Enough for you to be able to troubleshoot minor systems related issues independently.

Descriptive Statistics

Responses to the statement “your training included a section on aircraft systems. Enough for you to be able to troubleshoot minor systems related issues independently” were collected from twenty-six (96.3 percent) of the unmanned participants and sixty (100.0 percent) of the manned participants. Both groups, unmanned (*M = 1.31, SD = .55)* and manned (*M = 1.35, SD = .73)*, agreed with the statement; indicating a low safety concern in their organization (Figures 56 and 57).

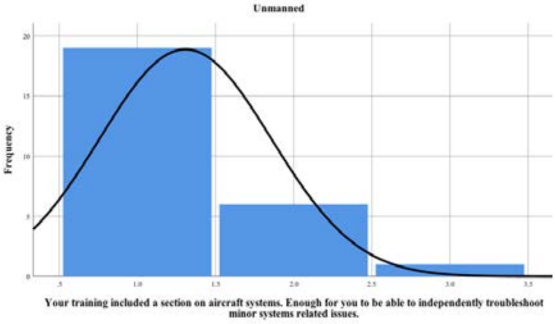


Figure 56. Histogram of 5.7 Unmanned.

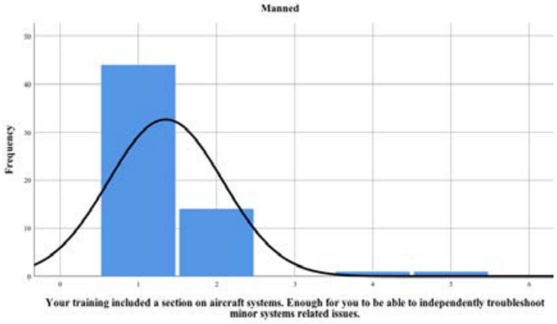


Figure 57. Histogram of 5.7 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both groups agreed with the statement and no statistically significant differences exist between groups (*U =778.00, P = .98).* Therefore, the null hypothesis cannot be rejected based on this statement.

5.9 As the PIC of a completed flight, you are responsible for writing up any known discrepancies that occurred before, during, or after your flight.

Descriptive Statistics

Responses to the statement “as the PIC of a completed flight; you are responsible for writing up any known discrepancies that occurred before, during, or after your flight” were collected from twenty-four (88.9 percent) of the unmanned participants and fifty-eight (96.7 percent) of the manned participants. Both groups, unmanned (*M = 1.08, SD = .41)* and manned (*M = 1.12, SD = .33),* agreed with the statement; indicating a low safety concern in their organization (Figures 58 and 59).

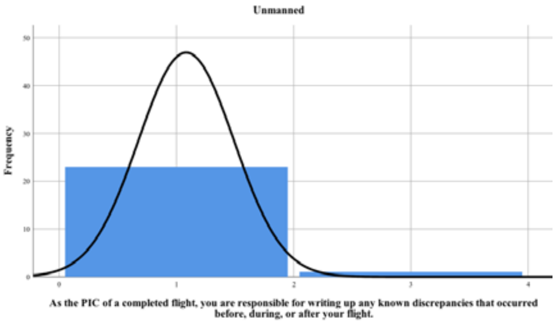


Figure 58. Histogram of 5.9 Unmanned.

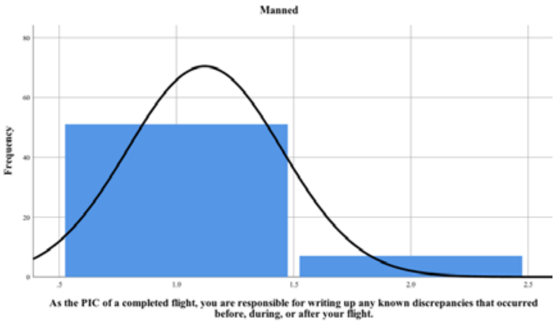


Figure 59. Histogram of 5.9 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both groups agreed with the statement and no statistically significant differences exist between groups (*U =644.50, P = .31).* Therefore, the null hypothesis cannot be rejected based on this statement.

5.10 Your training included sufficient instruction of the requirements of operating in the national airspace system per the Federal Aviation Administrations. To the extent that you, as the PIC, can reteach another of your peers.

Descriptive Statistics

Responses to the statement “your training included sufficient instruction of the requirements of operating in the national airspace system per the Federal Aviation Administrations. To the extent that you, as the PIC, can reteach another of your peers” were collected from twenty-four (88.9 percent) of the unmanned participants and sixty (100.0 percent) of the manned participants. Both groups, unmanned (*M = 1.33, SD = .82)* and manned (*M = 1.27, SD = .52)*, agreed with the statement; indicating a low safety concern in their organization (Figures 60 and 61).

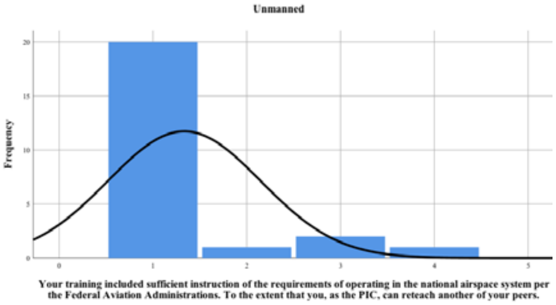


Figure 60. Histogram of 5.10 Unmanned.

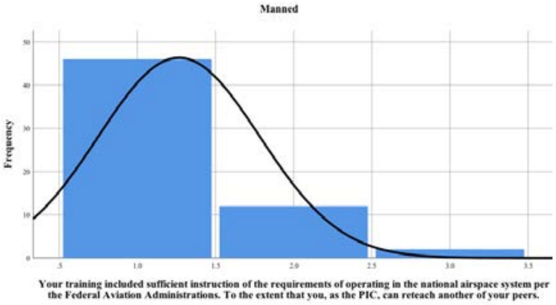


Figure 61. Histogram of 5.10 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both groups agreed with the statement and no statistically significant differences exist between groups (*U =690.00, P = .68).* Therefore, the null hypothesis cannot be rejected based on this statement.

6.2 Your organization produces and adheres to a strict set of Standard Operating Procedures (SOPs).

Descriptive Statistics

Responses to the statement “your organization produces and adheres to a strict set of Standard Operating Procedures (SOPs)” were collected from twenty-six (96.3 percent) of the unmanned participants and fifty-nine (98.3 percent) of the manned participants. Both groups, unmanned (*M = 1.19, SD = .40)* and manned (*M = 1.36, SD = .55),* agreed with the statement; indicating a low safety concern in their organization (Figures 62 and 63).

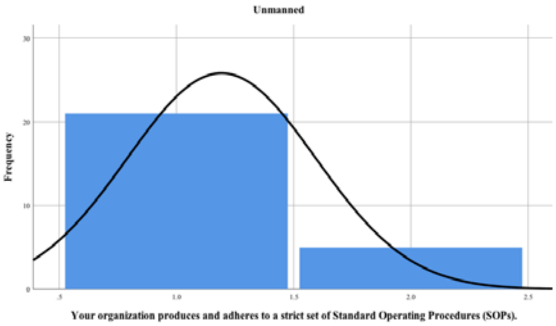


Figure 62. Histogram of 6.2 Unmanned.

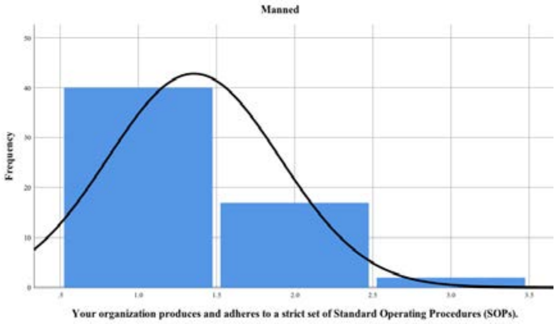


Figure 63. Histogram of 6.2 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both groups agreed with the statement and no statistically significant differences exist between groups (*U =662.50, P = .20).* Therefore, the null hypothesis cannot be rejected based on this statement.

6.5 Your organization values safety over mission success.

Descriptive Statistics

Responses to the statement “your organization values safety over mission success” were collected from twenty-five (92.6 percent) of the unmanned participants and sixty (100.0 percent) of the manned participants. Both groups, unmanned (*M = 1.32, SD = .69)* and manned (*M = 1.52, SD = .89),* agreed with the statement; indicating a low safety concern in their organization (Figures 64 and 65).

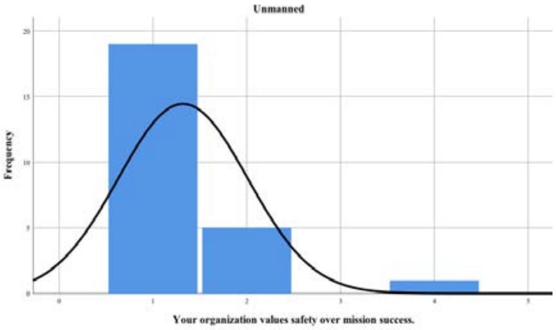


Figure 64. Histogram of 6.5 Unmanned.

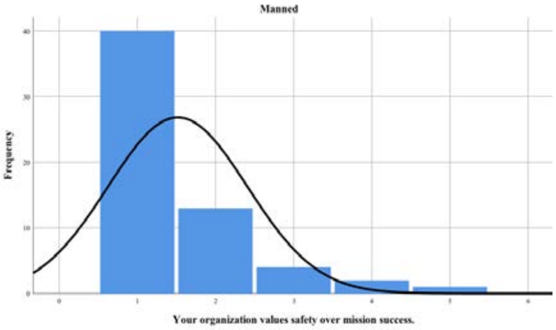


Figure 65. Histogram of 6.5 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both groups agreed with the statement and no statistically significant differences exist between groups (*U =670.50, P = .34).* Therefore, the null hypothesis cannot be rejected based on this statement.

6.9 Your organization is proactive, rather than reactive, in developing safety standards and initiatives.

Descriptive Statistics

Responses to the statement “your organization is proactive, rather than reactive, in developing safety standards and initiatives” were collected from twenty-six (96.3 percent) of the unmanned participants and fifty-eight (96.7 percent) of the manned participants. Both groups, unmanned (*M = 1.81, SD = .90)* and manned (*M = 1.66, SD = .98),* agreed with the statement; indicating a low safety concern in their organization (Figures 66 and 67).

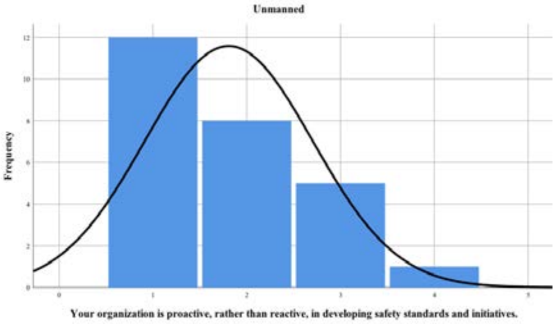


Figure 66. Histogram of 6.9 Unmanned.

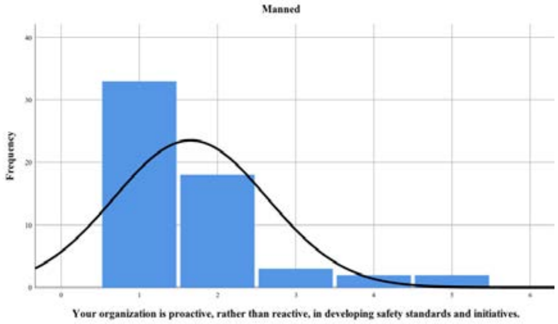


Figure 67. Histogram of 6.9 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both groups agreed with the statement and no statistically significant differences exist between groups (*U =656.50, P = .30).* Therefore, the null hypothesis cannot be rejected based on this statement.

6.10 Safety standards are well distributed to your entire organization to include, pilots, maintenance personnel, operations, etc.

Descriptive Statistics

Responses to the statement “safety standards are well distributed to your entire organization to include, pilots, maintenance personnel, operations, etc.” were collected from twenty-five (92.6 percent) of the unmanned participants and fifty-eight (96.7 percent) of the manned participants. Both groups, unmanned (*M = 1.60, SD = .91)* and manned (*M = 1.33, SD = .60),* agreed with the statement; indicating a low safety concern in their organization (Figures 68 and 69).

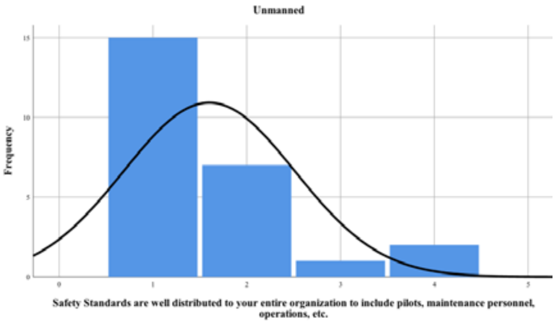


Figure 68. Histogram of 6.10 Unmanned.

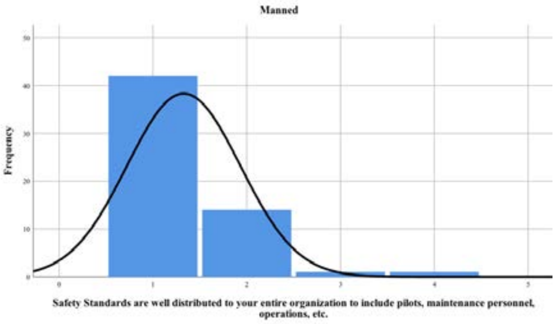


Figure 69. Histogram of 6.10 Manned.

Mann-Whitney U Test

A Mann-Whitney U Test concluded that both groups agreed with the statement and no statistically significant differences exist between groups (*U =620.50, P = .20).* Therefore, the null hypothesis cannot be rejected based on this statement.

CHAPTER V

DISCUSSION

Upon review of the literature and collected data, there is no significant difference in how safety is approached when comparing manned and unmanned aviators. Both groups tended to select responses that correlated with the safer or less risky options. The following discussion will walk through the fundamental data analysis pertaining to each research question, discuss limitations of the study, and suggest areas for future research.

Research Questions

Research Question I

The first research question asked how the perspective of safety differed between the manned and unmanned groups. A combination of nine survey items were analyzed two ways in an attempt to answer research question one. The one-way ANOVA performed on the Mean Safety Perception Rating (MSPR) yielded no significance between the two groups. The mean scores between unmanned (M=1.56) and manned (M=1.58) were nearly the same. Both groups indicated a healthy regard for safety. The second method looked at each individual survey item for significance. No significance was found for any of the nine survey items that underwent non-parametric statistic testing. The answer to research question one based on the results of this study is that there is no difference in how safety is perceived when comparing manned and unmanned aviators. Lack of significance in the statistical analysis of this survey may have been a result of the data collection tool. The survey allowed for broad distribution to a diverse population. However, it seems unlikely that participants felt any danger or stress during the survey. Different results might be obtained if the participants took part in various simulations that exhibited the characteristics of the safety scenarios presented in the survey. It is also likely that the participant's experience in manned aviation resulted in higher regard for safety. Of the unmanned participant's, eighty percent indicated some level of manned flight experience, with a majority having over one-hundred flight hours. As the unmanned industry continues to grow, the probability increases that unmanned operators may have little to no manned flight experience. The cost of manned flight training as a requirement for unmanned operations may inhibit industries looking to benefit from the low operating expense of small unmanned aircraft. Real estate firms, first response units, precision agriculture, drone racing, are just a few of the industries that benefit inexpensive, and sometimes disposable, unmanned aircraft. Bringing in participants that are involved with unmanned operations, with little to no manned flight experience would be an excellent place to continue the safety perception discussion.

Research Question II

Research question two assesses the difference in how manned and unmanned aviators perceive risk, given the difference in physical risk. Similar to research question one, question two was analyzed using both parametric and non-parametric statistical tests. The parametric test was conducted using a combined mean score for each participant across each survey item. The one-way ANOVA yielded no significance and comparing the mean between unmanned (M=3.89) and manned (M=3.78) tells a similar story. Method two utilized a non-parametric test to examine each variable on its own. Of the nine items analyzed only one returned results suggesting that a statistically significant difference exists between unmanned and manned aviators.

Survey item 4.5 asked participants to rate the risk involved with inadvertent flight into inclement weather. The Mann-Whitney U test reported that there was indeed a statistical difference between how unmanned (M=5.13) and manned (M=3.41) perceived the risk involved with inadvertent flight into weather. It was surprising to see that the unmanned group responded with the higher rate of risk. A likely answer to this lies not in the differences between aviators, rather in what equipment they are operating. Many small UAS must be operated within line of sight, and inadvertent flight into inclement weather would mean the partial or complete loss of situational awareness. Further analysis shows that unmanned aviators having served in the military (M=7.00) rated this risk higher than unmanned aviators that had not served in the military (M=4.31). Military UAS are typically constructed using composite materials laminated together to create a lightweight, durable airframe. However, these materials can be compromised during prolonged flight into inclement weather. Further research is required to determine the impact of inadvertent flight into inclement weather on unmanned aviators' risk perception.

Overall, the answer to research question two is that there is no significant difference in risk perception between manned and unmanned aviators. Similar to the first research question, participants were asked to subjectively rate risk while, most likely, sitting in a low-risk environment. Simulations or inducing different types of stress may provide more insight into how unmanned and manned aviators perceive risk. The risk tolerance of the participants may have also influenced the results. Participants with a higher tolerance for risk likely exhibit a safer perception of risk. Future variations of this study should find a way to measure risk tolerance and apply those findings to the individual's risk perception.

Research Question III

Research question three looks at the difference in unmanned and manned safety culture within their respective organizations. As with the previous two questions, question three was analyzed in two methods using both parametric and non-parametric tests. The first method used a one-way ANOVA and did not result in a statistically significant difference between unmanned (M=1.49) and manned (M=1.33) aviators in regards to how safe they perceive their organizations. The second method used the non-parametric Mann-Whitney U independent samples test to analyze each of the eleven variables on their own. All eleven tests returned results that showed there was no statistically significant difference in unmanned and manned safety cultures. While this result indicates a positive safety culture in general, many of the factors that affected the first and second research question should also be considered. Similar background experience between groups, low-stress testing environment, and subjective self-assessments may have contributed to the lack of statistical significance between groups.

Limitation of Study

This study was limited by several factors. Data accessibility, population size, population type, the maturity of the UAS industry, and accessibility to participants limited general applicability of this study and may have influenced the results.

Population Size

While the split of manned (n=60) and unmanned (n=27) may represent an accurate manned to unmanned pilot ratio in the real world, a more significant overall population would have allowed for higher power in the statistical analysis. The small sample size may have impacted the significance of the statistical analysis. Future studies replicating a similar analysis should aim for a more substantial total population.

Population Type

The small sample size also limited the types of participants, creating a narrower view of the manned and unmanned industries. This limitation likely exists due to difficulties in distributing the data collection tool to a diverse population. Accessibility and time constraints added to the difficulties in diversifying the manned and unmanned aviator groups. A more substantial population with an extended data collection period would have allowed for a more accurate statistical analysis.

Data Collection Method

Given the small size of the population, the survey tool used to collect data may have limited the ability of statistical analysis to determine differences between groups. If sample size could not be increased in future studies, simulations or interviews may help to verify the results of the survey.

The survey tool inherently has its own limitations as well. It is possible that participants were not completely honest in their responses and, consciously or subconsciously, selected an answer they deemed more acceptable. In an attempt to combat this, the anonymity of the individual was guaranteed. Participants may have also lacked interest in the topic and may not have thoroughly read or comprehended the statements or may have selected responses based on a particular bias.

The maturity of UAS Industry

The relative young age of the unmanned industry limits the potential sample size and population. The available pool of unmanned operators may have been suppressed due to regulatory constraints that keep unmanned aircraft from operating in the NAS. A more mature industry would have provided a diversified population in comparison to this study. For example, there were very few unmanned aviator participants' that did not also have manned experience. In the not too distant future, there may be a more significant number of solely unmanned aviators.

Future Research and Considerations

The future of unmanned aircraft is promising, and according to this study, the industry has the correct mindset with regards to safety. That being said, the limitations of this study warrant a review of the results when the UAS industry has matured and gained more significant operational access to the NAS.

Further research would benefit from more advanced data collection methods. Side by side simulations, non-flight related decision-making tests, and other tools could be used to compare further how the two groups regard safety. While understanding the safety culture in organizations provides a broad analysis of the aviation industry, it might not be critical to assess is future studies. Instead, more attention should be placed on safety and risk perception among aviators and other support personnel. As mentioned above, future research should find a way to measure risk tolerance as well. That factor may add weight to how participants perceive risk and safety.

This study's scope was limited to aviators. However, in both industries, there are multiple layers of support to include but not limited to mechanics, ground support personnel, flight dispatchers, and schedulers. Understanding how the safety attitude of these personnel affect the operation may also help in ensuring a safe operating environment for both manned and unmanned aviators and would be an exciting subject of future research.

Conclusion

This study attempted to predict potential problem areas in the fast-growing unmanned industry. The literature review revealed that several UAS accidents or mishaps resulted from pilot or operator error. The benefits of gaining knowledge of why these accidents occurred may help to smooth the path towards UAS integration into the National Airspace System. This small pilot study is a small step in analyzing how the unmanned and manned industries are similar and how they might differ. Understanding these relationships will assist in ensuring public perception remains favorable so that UAS may prosper for years to come.

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