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Correspondence and inquiries:

University Aviation Association
2787 N. 2nd St
Memphis, TN 38127
(901) 563-0505
hello@uaa.aero

OBJECTIVES

The University Aviation Association publishes the Collegiate Aviation Review International throughout each calendar year. Papers published in each volume and issue are selected from submissions that were subjected to a double-blind peer review process.

The University Aviation Association is the only professional organization representing all levels of the non-engineering/technology element in collegiate aviation education and research. Working through its officers, trustees, committees, and professional staff, the University Aviation Association plays a vital role in collegiate aviation and in the aerospace industry. The University Aviation Association accomplishes its goals through a number of objectives:

- To encourage and promote the attainment of the highest standards in aviation education at the college level
- To provide a means of developing a cadre of aviation experts who make themselves available for such activities as consultation, aviation program evaluation, speaking assignment, and other professional contributions that stimulate and develop aviation education
- To furnish an international vehicle for the dissemination of knowledge relative to aviation among institutions of higher learning and governmental and industrial organizations in the aviation/aerospace field
- To foster the interchange of information among institutions that offer non-engineering oriented aviation programs including business technology, transportation, and education
- To actively support aviation/aerospace oriented teacher education with particular emphasis on the presentation of educational workshops and the development of educational materials covering all disciplines within the aviation and aerospace field

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Collegiate Aviation Review International

Volume 38 | Issue 2 Peer-Reviewed Article #1

7-27-2020

Face Mask Effects of CO_2, Heart Rate, Respiration Rate, and Oxygen Saturation on Instructor Pilots

Andrew R. Dattel
Embry-Riddle Aeronautical University

Nicola M. O'Toole
Embry-Riddle Aeronautical University

Guillermina Lopez
Embry-Riddle Aeronautical University

Kenneth P. Byrnes
Embry-Riddle Aeronautical University

The COVID-19 pandemic has required people to take new measures to mitigate the spread of the communicable virus. Guidelines from health organizations, government offices, and universities have been disseminated. Adherence to these guidelines cannot be more critical for flight training. This study explored the effects face masks had on CO_2, heart rate, respiration rate, and oxygen saturation while wearing a face mask at an oxygen level simulated to 5,000 feet. Thirty-two instructor pilots (IP) volunteered to participate in the study. IPs spent 90 minutes in a normobaric chamber while wearing a cloth face mask or a paper face mask. Participants were measured before entering the chamber, at the 15-minute mark, at the 45-minute mark, at the 90-minute mark, and after exiting the chamber where they briefly removed their mask for a final measurement. No differences were found between type of face mask. Wearing face masks did not present any potential health or safety issues for the IPs. However, IPs did report moderate dislikes (e.g., comfort, issues with fatigue, restriction of movement) of wearing face masks. Although face masks may be a nuisance, it does not appear to create any health or safety issues at a simulated altitude of 5,000 feet.

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Dattel, A.R., O'Toole, N.M., Lopez, G., & Byrnes, K.P. (2020). Face Mask Effects of CO2, Heart Rate, Respiration Rate, and Oxygen Saturation on Instructor Pilots. *Collegiate Aviation Review International*, 38(2), 1-11. Retrieved from http://ojs.library.okstate.edu/osu/index.php/CARI/article/view/8038/7412

The outbreak of COVID-19 has brought about some drastic changes to our way of life. As more is learned about the virus, cities and counties look to protect citizens and allow a return to normal. The Centers for Disease Control and Prevention (CDC) (2020) issued a recommendation that citizens wear cloth masks to protect themselves and others.

Many aspects of day-to-day life can be adjusted to allow for social distancing to help reduce the risk of community-based spread of COVID-19. The unique nature of flight training does not allow for social distancing in the aircraft. When Embry-Riddle Aeronautical University decided to resume flight training, face masks usage for both instructor pilots (IP) and students were one of the many safety precautions that were made mandatory.

After a few weeks of flight training some of the IPs expressed concerns about discomfort from wearing a mask and some said face masks cause them to feel fatigued. During respiration, a gas exchange occurs when oxygen is inhaled and absorbed into the body and carbon dioxide (CO_2) is exhaled. When exhaling into a mask, there is a potential to inhale a greater amount of carbon dioxide, due to the exhaled carbon dioxide being trapped between the face and mask. One symptom of an excess of carbon dioxide in the blood, or hypercapnia, is fatigue (Jewell, 2005). Carbon dioxide can be measured in the air exhaled, by using a capnograph. A normal amount of carbon dioxide when measured by a capnograph is between 35 and 45 mm HG (Sullivan, 2015). If the mask is trapping carbon dioxide rich air, it could result in not enough oxygen being brought into the lungs during respiration. Lack of oxygen being absorbed through respiration could cause hypoxia. The Cleveland Clinic lists the symptoms of hypoxia ranging from shortness of breath, to confusion and death (Hypoxemia, n.d.). The amount of oxygen in a person's blood can be measured using a pulse oximeter. A normal pulse oximeter reading will vary between 95-100% (Mayo Clinic, 2018). The effect of hypoxia due to an increase in altitude in non-pressurized aircraft has been well documented and is required to be taught at the Commercial pilot level (FAA, 2015). Pilots are trained to know what symptoms to look for and how best to react.

Relatively little research has been conducted regarding the physiological effects of wearing a mask. Roberge, Coca, Williams, Powell and Palmiero (2010) conducted a study with healthy health care workers using filtering facepiece respirators (FFR) or N95 masks. The study looked at differing workloads for a 1-hour duration and studied, CO_2 as one of the many physiological effects. The study concluded that there were no significant physiological effects of wearing an FFR for 1 hour. However, two of the participants' peak CO_2 reached 50 mm HG at the end of the 1-hour period, suggesting that use of this type of mask beyond an hour may have negative effects. It is important to note that an FFR is designed to fit tightly to the face so it can filter out 95% of airborne particles unlike a cloth or paper/surgical mask (Center for Devices and Radiological Health, n.d.).

Schmidt (2020) quoting a representative from the CDC:

> The CO_2 will slowly build up in the mask over time. However, the level of CO_2 likely to build up in the mask is mostly tolerable to people exposed to it. It is unlikely that wearing a mask will cause hypercapnia. (para. 5)

A later study by Roberge et al., (2012) considered the physiological effects of wearing a surgical mask. Participants walked on a treadmill for 1 hour wearing a surgical mask and for an additional hour without a mask while various physiological measurements were taken. In the analysis, Roberg et al. concluded that there was no physiological impact from wearing a surgical mask. There was a statistically significant rise in transcutaneous carbon monoxide; however, it would not be medically significant in a healthy individual. The CO_2 levels still remained in the normal range between 35 to 45 mm HG.

No studies relating to physiological effects of face mask use in an aviation context have been found. This study looked at the amount of carbon dioxide exhaled over time at a simulated altitude of 5,000 feet. Additionally, a comparison was made between paper/surgical masks and cloth masks.

Methodology

Participants

Thirty-two (26-male, 6-female) instructor pilots volunteered to participate in this study. Mean age of participants was 24.31 years (*SD* = 2.98). All participants were currently employed and received the IP hourly rate for the 2 hours in the study. Half the participants wore a cloth face mask during the study and the other half wore a paper/surgical face mask.

Materials

The Smiths Medical 8401 Capnocheck II capnograph (see Figure 1) with cannula was used to measure End-tidal CO_2, heart rate (HR) respiration rate (RR), and O_2 saturation. Cloth face masks and paper face masks were provided to participants, if necessary, to assure an equal distribution of face mask types per group. A normobaric altitude chamber was used to reduce oxygen levels from 20.9% at sea level to 17.61% —the typical oxygen level at an altitude of 5,000 feet. To simulate activities that may occur in an aircraft, aeronautical charts were provided, as well as a nut and bolt to simulate any turning of knobs. A survey (see Appendix A) included self-reports of opinions concerning wearing face masks.

Figure 1. Capnograph device.

Procedure

Eight sessions were scheduled to accommodate four participants at a time. Guidelines as directed by the CDC and as mandated by the University were strictly followed. There were two empty seats between each participant in the normobaric chamber. Participants were provided with hand sanitizer and were required to wear masks at all times — except for a few minutes before entering the chamber and for a few minutes after exiting the chamber.

After signing the consent form, each participant's CO_2, HR, RR, and O_2 saturation were measured with the capnograph – first with the face mask off, then with the face mask on. Participants were provided with their own cannula. Participants entered the normobaric chamber at a simulated altitude at 2,000 feet, when it was then raised to a simulated altitude of 5,000 feet. At the 15-minute, 45-minute, and 90-minute mark in the chamber, participants' CO_2, HR, RR, and O_2 saturation were again measured. Face masks were never removed inside the chamber. Throughout the 90-minute session, participants were periodically instructed to look up airport identifiers and runway elevations on an aeronautical sectional chart, raise their arms for 10 seconds to simulate adjusting navigation/communications controls, read a check-list, and twist a nut on and off a bolt. Participants were not aware of the exact moment physiological measurements were taken or, the time when they were to exit the normobaric chamber.

After 90 minutes, participants exited the chamber. Participants then completed the survey. Before completing the study, participants' CO_2, HR, RR, and O_2 saturation were measured again (one at a time) with the face mask off.

Results

A 2 (Type of face mask) x 6 (Time of collection) Mixed ANOVA was conducted for CO_2 level, HR, RR, and O_2 saturation. Main effects for Time of collection were found for all four measurements: CO_2: $F(5, 150) = 2.969$, $p = .014$, $\eta_p^2 = .090$; HR: $F(5, 150) = 11.782$, $p < .001$, $\eta_p^2 = .282$; RR: $F(5, 150) = 2.347$, $p = .044$, $\eta_p^2 = .073$; O_2: $F(5, 150) = 10.412$, $p < .001$, $\eta_p^2 = .258$ (See Figures 2 a, b, c, and d). No other effects were found.

CO_2 levels were significantly higher before entering the normobaric chamber when the face mask was off, as well as after donning the face mask, but immediately before entering the chamber when compared to the 45-minute mark inside the chamber when the face mask was on and when immediately tested after exiting the chamber (See Table 1). LSD post hoc analyses showed higher HR before entering the chamber (both with face mask off and after donning the face mask) compared to all other time measurements when in the chamber and when tested after exiting the chamber. LSD post hoc analyses showed RR was higher after exiting the chamber compared to after donning the mask before entering the chamber, at the 15-minute mark, and at the 45-minute mark. Post hoc analyses found O_2 saturation to be lowest at the 15-minute mark when compared to all other measured times. In addition, O_2 saturation was highest after exiting the chamber when compared to all other measured times.

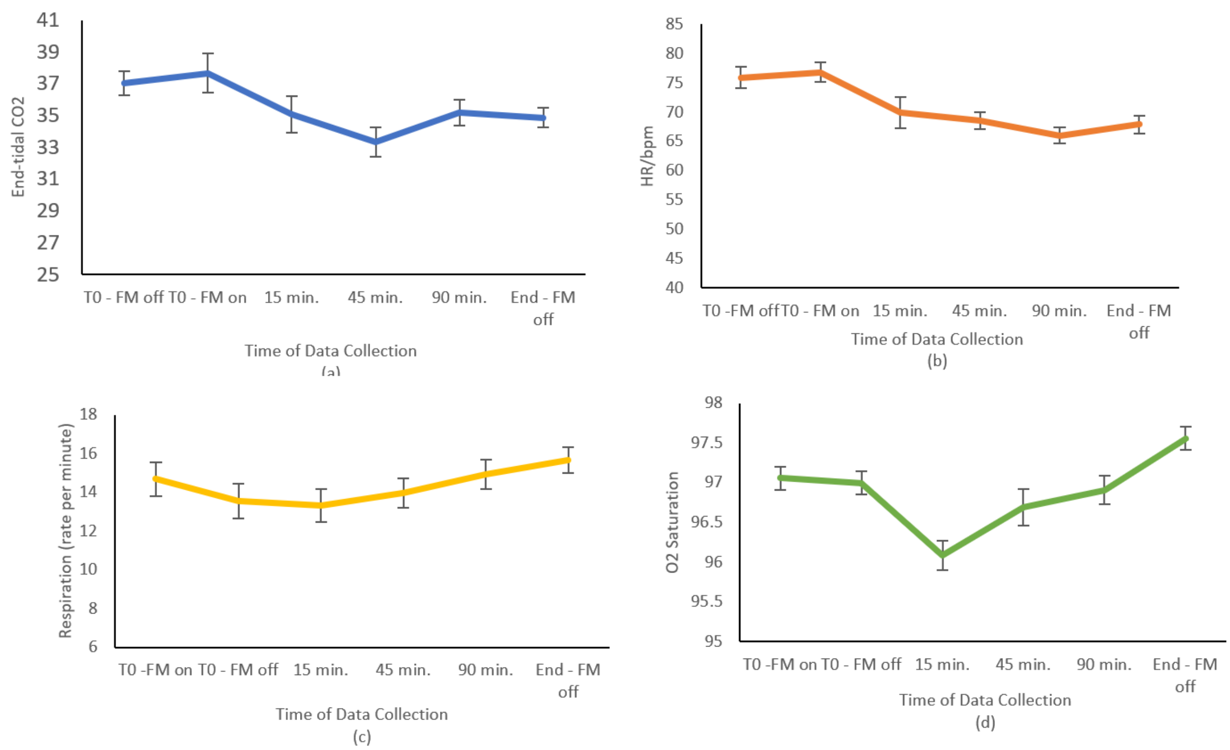

Figure 2(a)-(d). Changes in CO_2, Heart Rate, Respiration Rate, and O_2 Saturation Over Time of Data Collection.

Table 1
Means for CO_2, HR, RR, and O_2 Saturation by Type of Face Mask

Time	**CO_2**			**HR**			**RR**			**O_2 Saturation**		
	Cloth	Paper	Total	Cloth	Paper	Total	Cloth	Paper	Total	Cloth	Paper	Total
T_0 – Mask off	37.31	35.28	36.30^{A}	77.50	74.38	75.94^{C}	15.88	13.50	14.69	96.75	97.38	97.06^{Fg}
	(4.48)	(4.05)	(4.32)	(10.46)	(9.47)	(9.94)	(4.73)	(5.19)	(5.03)	(.93)	(.72)	(.88)
T_0 – Mask on	37.22	38.09	37.66^{B}	78.19	75.5	76.84^{D}	13.88	13.25	13.56^{e}	97.06	96.94	97.00^{Fg}
	(9.33)	(3.52)	(6.95)	(10.11)	(8.33)	(9.21)	(4.49)	(5.70)	(5.05)	(.77)	(.85)	(.80)
15-minute mark	35.75	34.38	35.06	74.44	65.56	70.00^{cd}	14.06	12.56	13.31^{e}	95.75	96.44	96.09^{fg}
	(6.33)	(6.97)	(6.58)	(11.32)	(18.0)	(15.5)	(4.14)	(5.39)	(4.79)	(1.13)	(.96)	(1.09)
45-minute mark	34.84	31.84	33.34^{ab}	68.88	68.31	68.59^{cd}	14.75	13.19	13.97^{e}	96.63	96.75	96.69^{Fg}
	(4.79)	(5.67)	(5.39)	(9.53)	(6.44)	(8.00)	(3.44)	(5.10)	(4.35)	(1.31)	(1.29)	(1.28)
90-minute mark	35.75	34.63	35.19	65.88	66.25	66.06^{cd}	15.38	14.50	14..94	96.94	96.88	96.91^{Fg}
	(4.64)	(4.65)	(4.60)	(9.70)	(6.08)	(7.97)	(3.63)	(4.89)	(4.26)	(1.00)	(1.02)	(1.02)
After exiting chamber (Mask off)	35.78	33.94	34.86^{ab}	69.56	66.25	67.91^{cd}	16.69	14.63	15.66^{E}	97.31	97.81	97.56^{FG}
	(3.23)	(3.68)	(3.53)	(9.59)	(6.96)	(8.41)	(4.25)	(3.20)	(3.85)	(.95)	(.66)	(.84)

Mean (*SD*)
Subscripts = pairwise comparison differences (Capital letter indicates higher than respective lower-case letter)

A post study six-question survey was conducted. Questions asked about how secure the face mask was to the face (Range: 1 - extremely loose to 10 - extremely tight); comfort level (Range: 1 - no effect on comfort to 10 - extremely uncomfortable); if face mask made participant feel warmer/hotter (Range: 1 - no effect on perceived body temperature to 10 - feeling extremely hot); if face mask restricted movement (Range: 1 - no effect on movement to 10 - greatly restricted movement; if face mask contributed to overall fatigue (Range: 1 - no impact on fatigue to 10 - very fatigued); and if face mask contribute to fogged glasses (1 - Range no fogging occurred to 10 - extreme fogging occurred).

A MANOVA of all survey questions, except for the question of fogging the glasses (due to low *n*) comparing groups (cloth face mask and paper face mask) was conducted. An independent means *t*-test showed no differences between groups for the glass fogging question. See Table 2 for descriptive statistics. No differences between groups were found for any of the variables.

Table 2
Descriptive Statistics for Survey

Question	**Cloth FM**	**Paper FM**	**Total**
FM Secure	6.66	6.56	6.61
	(1.38)	(1.97)	(1.67)
Comfort	5.44	5.44	5.44
	(2.28)	(1.66)	(2.05)
Warmer/Hotter	4.69	4.56	4.63
	(2.70)	(2.37)	(2.50)
Movement Restricted	2.63	2.5	2.56
	(2.06)	(2.16)	(2.08)
Fatigue	3.945	4.25	4.09
	(2.46)	(2.72)	(2.56)
Fog	4.8	7.0	5.9
	(3.93)	(3.39)	(3.66)
	$n = 5$	$n = 5$	$n = 10$

Correlations were conducted among responses for all six questions. Table 3 shows that comfort, feeling warm or hot, and restriction of movement and fatigue all positively correlated with each other. Restriction of movement is also positively correlation with fogging of glasses.

Table 3
Correlations of Survey Questions

	2	3	4	5	6
1. FM Secure	-.057	-.203	-.153	-.112	-.058
2. Comfort	-	.601**	.471**	.585**	.165
3. Warmer/Hotter	-	-	.396*	.642**	.303
4. Movement Restricted	-	-	-	.585**	.659*
5. Fatigue	-	-	-	-	.364
6. Fog (*n* = 10)	-	-	-	-	-

*< .05
**< .01

All four physiological measurements (CO_2, HR, RR, and O_2 saturation) were averaged for each time effect. A correlation was conducted for the four averaged physiological measurements. CO_2 and O_2 saturation were negatively correlated $r(32) = -.57$, $p = .001$. CO_2 was also negatively correlated with the survey question about how secure the face mask fit $r(32) = -.364$, $p = .041$ where the tighter a fit the participant reported the face mask, the lower the CO_2. Participants who reported greater discomfort wearing the face mask showed higher heart rate $r(32) = .476$, $p = .005$.

Discussion

Although there were some variations in the measurements of CO_2, O_2, HR and RR; at no point did the CO_2 rise above the normal range of 35 to 45 mm HG. Additionally, O_2 saturation did not fall below 95%, the generally accepted minimum normal percentage. There were no significant differences between mask types.

In terms of IP perception of the security of the mask, comfort, feeling hot or warm from the mask, restricted movement from the mask and fatigue; there was no significant differences between the two mask types. However, these variables were positively correlated with each other. The self-report of discomfort, but with little change in physiological measurements and performance is supported by previous studies in health care (Shenal, Radonovich, Cheng, Hodgson, & Bender, 2012) and education (Coniam, 2005).

Interestingly at the 45-minute measurement the CO_2 measurement dropped to 33 mm HG. This is often associated with a condition called Respiratory Alkalosis, which can be an effect of hyperventilation. The respiration rates for the participants at the 45-minute mark were normal. There appears to be a lull for all physiological measurements at the 45-minute mark, as well as a lull in conversation between IPs in the normobaric chamber at the 45-minute mark, which could explain slower breathing and HR that would lower CO_2 reading. Nonetheless, CO_2 rose back above 35 mm HG by the 90-minute mark.

Limitations

The chamber used to simulate 5,000 feet is a normobaric chamber, therefore the amount of oxygen present was decreased, but the pressure was maintained at sea level. The possible error this may cause is thought to be minimal. Additionally, the temperature remained constant in the normobaric chamber. On a climb from sea level to 5,000 feet, the temperature may change by 15° to 20°F. We do not know how differences in ambient temperature affect these physiological measurements. However, on a typical summer day, the temperature at 5,000 feet would be close to room temperature.

The activity level between the participants varied. Some groups talked animatedly amongst themselves and other groups were almost silent. This could have induced variations in the physiological readings. As in most behavioral studies, participants are aware they are being observed. The Hawthorne Effect (Snow, 1927) states that participants may change their behavior just because they know they are being observed, which consequently can confound internal validity. One issue that could have potentially affected the outcome of this study is that participants adjusted their breathing because they knew they were being observed. However, there are three reasons why it is unlikely that participants' behavior was affected in such a way to confound the results of this study. First, many of the participants were engaged in conversation, which would have decreased their focus of being observed. Second, participants were not told of the exact times measurement would be taken and the exact time the study would end. Third, there is evidence that the Hawthorne Effect has never been or has infrequently contributed to confounding effects in behavioral studies (Levitt & List, 2011).

Conclusions

The type of mask worn during an average 90-minute flight-training mission does not appear to increase the amount of CO_2 retained by the body. Additionally, face masks do not appear to hinder the body's ability to attain oxygen. IP perception about the adverse effects of the face mask appears to be moderate. However, with greater use and more familiarity wearing face masks, it is expected that this nuisance factor of the face mask will attenuate. Further testing in a flight simulator, where pilots are actively engaged with all aspects of flight (e.g., moving controls, communicating with Air traffic Control) is warranted. This study could also be repeated in flight with an observer monitoring physiological measurements.

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Appendix A

Please answer the following questions.

Please select your gender _______Male ________Female

Please provide your Age___________

What type of mask did you wear today? ______Cloth ______Paper

Please respond to the following questions based on a range of 1 to 10.

1. How well did the mask secure to your face?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10

Extremely loose — Extremely tight

2. How did wearing the mask affect your overall comfort level?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10

Had no effect on my comfort level — Made me extremely uncomfortable

3. Do you feel that wearing the mask made your body feel warmer/hotter?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10

Wearing the mask had no effect On my perceived body temperature — Wearing the face mask made feel extremely hot

4. Did wearing the mask restrict your physical movement (e.g., reaching for controls, turning your head) in any way?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10

Had no effect on my movement — Greatly restricted my movement

5. Do you feel that wearing the mask contributed to your overall fatigue?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10

Mask had no impact on my fatigue — Mask made me very fatigued

6. If you wear glasses, did wearing the mask result in your glasses fogging?

1----------2----------3----------4----------5----------6----------7----------8----------9----------10

No fogging at all occurred — Extreme fogging of my glasses occurred

Thank you for completing the survey. Please feel free to add any additional comments._______________

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8-2-2020

Developing a Competency Learning Model for Students of Unmanned Aerial Systems

Damon J. Lercel
Purdue University

Joseph P. Hupy
Purdue University

Over the past decade, Unmanned Aerial Systems (UAS), along with commercial UAS pilots, have become an established and increasingly regulated industry. Unfortunately, in the U.S. the number of near misses and incidents involving unsafe UAS operations is increasing dramatically. Additionally, industries looking to adopt UAS technologies not only require trained professionals to ensure safe and legal operations but may look for competencies that go well beyond the minimum regulatory requirements. To date, research regarding the higher order learning outcomes and competencies that are expected of UAS university graduates is lacking. Therefore, this research attempts to provide perspective of the core competencies that industry organizations may desire in a UAS graduate and, by extension, in a UAS professional. This paper describes the methods used to identify core UAS competencies, and presents a UAS Competency Learning Model that may help educators better prepare graduates for successful industry careers. Researchers utilized a multi-phase process over an 18-month period using both quantitative and qualitative methods, which included literature reviews, surveys, interviews, focus groups, and attendance at UAS industry events. Ultimately, from this research emerged the following six UAS competencies: Leadership, Technical Excellence, Safety and Ethics, Analytical Thinking, Teamwork, and Entrepreneurship.

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Over the past decade, Unmanned Aerial Systems (UAS) have grown from a hobbyist curiosity, to a disruptive technology, to what is now becoming an established and increasingly regulated industry. This rapid growth would be significant in any industry and remains unprecedented within aviation. For example, the United States (U.S.) issued its first manned pilot certificate in 1927. Almost 100 years later, the Federal Aviation Administration (FAA) has certified over 672,000 manned pilots in the U.S. In contrast, since the FAA enacted Part 107 regulation for small UAS in August of 2016, they have issued over 170,000 remote pilot certificates, which already comprises over 20% of the total pilot population (FAA, 2016, 2020e). The new Part 107 regulation was a first step in enabling broader commercial UAS operations in the U.S., but as the number of UAS pilots continues to grow and the industry evolves, there also comes a growing need to train and educate this emerging skills-based workforce.

With the explosion of UAS platforms and pilots, in addition to the already numerous Radio Control (RC) model aircraft, the FAA's approach to ensuring the safety of the National Airspace System (NAS) for all users has evolved over time as the technology has developed and the number of UAS has increased. Today there are over 1.5 million unmanned aircraft registered in the United States, with 420,000 registered for commercial use. The number of unmanned aircraft far exceeds the approximate 250,000 registered manned aircraft (FAA, 2020a). The FAA (2020b) continues to work towards developing policies and technologies that will expand future UAS operations beyond the current Part 107 limitations and increase integration into the NAS. These future operations include services such as package delivery and urban air mobility.

The FAA foresees UAS operations seamlessly integrating with manned aircraft in the NAS (FAA, 2020b, 2020d). Throughout this integration process, there will be more opportunities for public and private sector research to enable UAS to fly in the NAS with manned aircraft. Pilot and aircraft certification and training, airspace, safe separation of aircraft, air traffic procedures, and regulations will need to be developed as UAS operations and technologies evolve.

Unfortunately, in the U.S. the number of near misses and incidents involving unsafe UAS operations is accelerating. According to the FAA, reports of unmanned aircraft (UAS) sightings from pilots, citizens and law enforcement have increased dramatically over the past two years. The FAA now receives more than 100 such reports each month (FAA, 2020c). These unsafe operations challenge the economic opportunities and public benefit that UAS stands to provide (GAO, 2018). A properly trained and certificated workforce is a precursor to safe UAS operations and advancement of any socio-economic benefits. Additionally, industries looking to adopt UAS technologies not only require trained professionals to ensure safe and legal operations *but may require competencies that go well beyond the minimum regulatory requirements*.

There seems to be little agreement in the literature on the definition of a competency. Jubb and Robotham (1997) write that: "It still remains the case that a precise and widely accepted definition of competences continues to elude both those researching the field and trainers themselves" (p. 171). However, from an educational and training perspective it is generally accepted that competency refers to the underlying attributes of a person such as their knowledge, skills or abilities (Hoffmann, 1999). While discussing competency-based education in aviation, Kearns, Mavin, and Hodge (2016) suggest competency "means having a specific ability to do something that can be defined in advance" (p. 10), adding a competency may include knowledge, skills, attitudes, values and understanding that enable competent performance. Bernstein (2000) relates competency with one's performance – simply assessing a person's behavior for a given situation. The International Civil Aviation Organization (ICAO) defines competency as a combination of skills, knowledge and attitudes required to perform a task to the prescribed standard (2013). Defining competencies within these contexts places a focus on the required inputs of individuals to achieve competent performance. By describing the knowledge, skills or abilities required of competent performers, the inputs needed for the development of a learning program may be better defined.

The FAA regulation prescribes knowledge of the limitations and requirements to operate a small UAS in the National Airspace (NAS). For example, the operator must maintain visual sight of the UAS, operate no higher than 400 feet above ground level, and maintain minimum clearances from clouds (FAA, 2016). ASTM International (ASTM, 2020), formerly known as the American Society for Testing and Materials, developed a defined set of UAS pilot training standards. Similar to FAA regulation, a review of these standards also found an overwhelming focus on operational limitations, safety, and compliance. Likewise, the ICAO's focus is on ensuring a safe, efficient, secure, and sustainable civil aviation sector. In its Manual on Remotely Piloted Aircraft Systems (RPAS), the ICAO writes that their purpose is to provide "an international regulatory framework…and guidance material, to underpin routine operation of RPAS throughout the world in a safe, harmonized and seamless manner comparable to that of manned operations" (ICAO, 2015, p. 5).

Based on the literature's definition of competency in the context of education, these polices fall short of prescribing UAS competencies. Furthermore, although these organizations prescribe policy surrounding safe and legal UAS operations, they do not describe the competencies, or additional knowledge, skills, and abilities that employers may require of UAS professionals.

To date, research regarding the higher order learning outcomes and competencies that are expected of UAS university graduates is lacking. This is likely due to the infancy of the UAS ecosystem. Such a dearth of information presents significant barriers toward development of a UAS program that can properly address industry demands while keeping pace with technological developments. Despite these challenges, a detailed review of emerging patterns and trends within the UAS industry provides a plethora of information for creation of a UAS program that addresses both safety and technological concerns.

This research provides perspective into the core competencies that industry organization may desire in a UAS graduate and, by extension, in a UAS professional. The objective of this paper is to describe the methods used to identify these core competencies, with the goal of developing a UAS Competency Learning Model that may help educators better prepare graduates for successful industry careers. Ultimately, this Model may be used as a foundation for future research.

Methodology

A preliminary review of UAS programs at other universities and job postings for UAS pilots/operators, and mission specialists (in a wide variety of domains such as agriculture, law enforcement, geospatial intelligence, etc.) revealed that UAS graduates ideally will have a holistic understanding of the UAS ecosystem and technology. Key to this worldly approach is for the UAS graduate to grasp proper UAS application, how to safely and effectively operate a UAS in the NAS, and how to manage UAS operations at the enterprise business level.

The cross-disciplinary nature of UAS has both technical and personal benefits to diverse student populations across a diverse and increasing number of applications. Ideally, a UAS educational program should accommodate and adapt to future changes in UAS technology, market trends, and FAA policy. Such an approach produces well-rounded students with diverse marketable skills sets that appeal to a wide range of job markets and research fields, now and into the future.

Market and technological trends demonstrate that the UAS graduate need not be an expert in a single discipline, such as engineering, aviation policy, or data science; ideally, they have a well-rounded knowledge of UAS related realms (Bennett, Nex, Gerke, Zevenbergen, & Stöcker, 2017; Colomina & Molina, 2014; Watts, Ambrosia, & Hinkley, 2012). Table 1 provides a non-comprehensive summary of the typical skills often employed in the UAS industry. To teach each of these skills in a detailed manner within the resource limitations of a degree program would be unfeasible, so there is a need to provide an overall UAS education, yet focus on key areas based upon key emergent trends in the UAS industry.

Table 1.
Example of UAS Industry Skills

Technology	Operations	Data	Policy
• Maintenance/Repair • System Evaluation • Integration • Sensors	• Safety Management • Mission Planning • Crew Resource Management • Software Apps	• Management • Processing • Analyses • Remote Sensing • GIS	• Regulations • Safety • Ethics • Training • Security

This study involved a multi-phase process over an 18-month period using both quantitative and qualitative methods, which included literature reviews, surveys, interviews, focus groups, and attendance at UAS industry events. Study participants included FAA and industry representatives; events included the Association of Unmanned Vehicle Systems International (AUVSI) annual Xponential show, the annual FAA UAS Symposium, Environmental Systems Research Institute’s (ESRI) User Conference, and Aviation Accreditation Board International (AABI) meetings.

The qualitative data was primarily collected from a diverse group of subject matter experts across the UAS industry. Researchers utilized this data to gain perspective on the current and future competencies needed by the industry and to understand their competency priorities. From the qualitative data, researchers developed a survey instrument to collect quantitative data from across the broader population. To achieve the objective toward development of a theoretical competency model, these researchers developed a phased approach outlined below.

Phase 1

Phase 1 focused on gaining perspective of the UAS ecosystem and, more specifically, the aspects related to workforce development and demand, employer requirements, and economic trends. The authors conducted an extensive literature review, which included reviewing regulatory documents, demographic data, industry publications, economic and market forecasts, UAS related job postings, university's UAS curriculum, and related workforce studies.

Phase 2

In Phase 2 qualitative data was gathered across several activities. First, researchers established a UAS Industry Advisory Board (IAB) comprised of a diverse network of eight UAS industry leaders. Researchers engaged the IAB to discuss and affirm the findings from Phase 1, gain perspective and a deeper understanding of industry workforce priorities, and support development of a UAS workforce survey instrument. Next, researchers attended key UAS industry events, which included discussion sessions related to UAS workforce competencies, applications, and the UAS ecosystem. Further building upon Phase 1, the focus of Phase 2 was to gather a broader perspective of attitudes and opinions regarding the current and future workforce needs. At these events the authors attended day long workshops concerning development of a Safety Management System (SMS) and Crew Resource Management (CRM) (Ginnett, 2019). They also conferred with various attendees and conducted informal interviews regarding sought after competencies in the UAS industry. Researchers recorded notes of these discussions and collected marketing and technical literature, interviewees included representatives from the FAA, UAS hardware and software companies, manufacturers and service providers. Additional informal interviews were conducted with UAS faculty from various universities, students, and recent graduates. No identifying information was collected nor was audio or video recording utilized.

Phase 3

Phase 3 combined input gathered in Phase 1 and 2 to generate and distribute a survey that allowed for a broader collection of quantitative data to aid in generating a theoretical competency model. This survey instrument attempted to identify and prioritize the top UAS competencies required of current and future UAS professionals.

Survey taxonomies were developed from Phase 1 and 2 research and in consultation with the IAB. With the list of competencies and their respective knowledge, skills and abilities developed, a survey was created that assessed the broader industry population. Survey participants ranked the importance of competencies, and then second, ranked the importance of knowledge, skill and ability items corresponding to each competency. Before distribution across the survey population, researchers tested the survey across a beta group of 20 individuals, which was comprised of industry representatives (including IAB members), other faculty members, and graduate students. Only minor edits and adjustments to technical settings were required. Researchers recruited survey participants by utilizing publicly available information obtained from FAA and other industry databases. Researchers emailed a web-based online survey instrument to 2,856 UAS professionals. Survey responses were completely anonymous and collected using the Qualtrics online survey software platform. Survey participants were asked to select their top three competencies and rank these three competencies in order of importance. Competencies were ranked by mean (M) score.

Phase 4

Phase 4 was conducted in parallel with Phase 3 efforts and involved a basic text-mining exercise of online UAS job postings. Sources included popular aviation related online job boards, such as Indeed, JS Firm, AVJobs, and several others. Researchers collected text from 72 UAS job postings. Microsoft EXCEL software with the Analytic Solver Data Mining add-in was used for the text analyses. An initial word frequency indexing was conducted to identify common non-value or stop words, which were then removed (Manning, 2008). From this index, researchers identified key words and performed a stemming exercise. Stemming removed derivational and inflectional affixes and reduced the word down to its root or stem, which improved the data retrieval process (Jabbar, Iqbal, Akhunzada, & Abbas, 2018). Trigrams were then created for stem words with counts greater than 40 to help improve context and perspective of the job requirements. These data were then reviewed by researchers to develop categories ranked by frequency of stem word count and trigrams. The results of this text mining exercise were then compared with the workforce survey results.

Results and Discussion

The Competency Gap

As part of this study, researchers evaluated industry's perspective of the requirements of the FAA Part 107 airman certificate and industry's requirements of UAS professionals. The results indicate a competency gap may exist between the regulatory requirements and what industry requires of UAS professionals. This finding suggests a need for additional education and training for current and future UAS professionals and is consistent with findings from previous research regarding FAA certification of Aviation Maintenance Technicians (Lercel et al, 2015; Gray, 2009). Survey participants were asked three questions regarding newly certificated FAA Part 107 Remote Pilots. The questions and the associated results are shown here in Table 2.

Table 2.
Survey results regarding competency of newly certificated FAA Part 107 Remote Pilots

Survey Question	Agree	Neither Agree or Disagree	Disagree
Do newly certificated FAA Part 107 remote pilots have the proper level of training that is required to be productive?	20%	25%	55%
Do the FAA Part 107 certificate requirements adequately prepare a new remote pilot to enter the workforce?	28%	23%	49%

Do newly certificated FAA Part 107 Remote Pilots have the proper level of training to operate safely?	28%	29%	43%

Comments from survey respondents and interviewees affirm these findings that meeting the minimum regulatory requirements do not adequately prepare a person for the UAS industry and do not ensure the level of safety required by industry.

Competency Model Trends

Preliminary results gathered in phases one and two demonstrated that UAS is driven predominantly by trends in the Aerospace and Geospatial industries, coupled with FAA regulatory policy and legislative mandates. Along with competency in the realm of aerospace (Figure 1), the UAS graduate must maintain certain core skills associated with the Geospatial Competency model (Figure 2). Both the Aerospace and Geospatial competency models are grounded in three foundational learning theories: (1) Bloom's (1956) theory of integration of the problem-based inquiry and the learning experience itself; (2) Litzinger, Wise, & Lee (2005) theory of relationship between level of individual maturity and level of learning; and (3) Cervero (1986) theory of learning as a by-product of inquiry rather than an outcome of a teaching process.

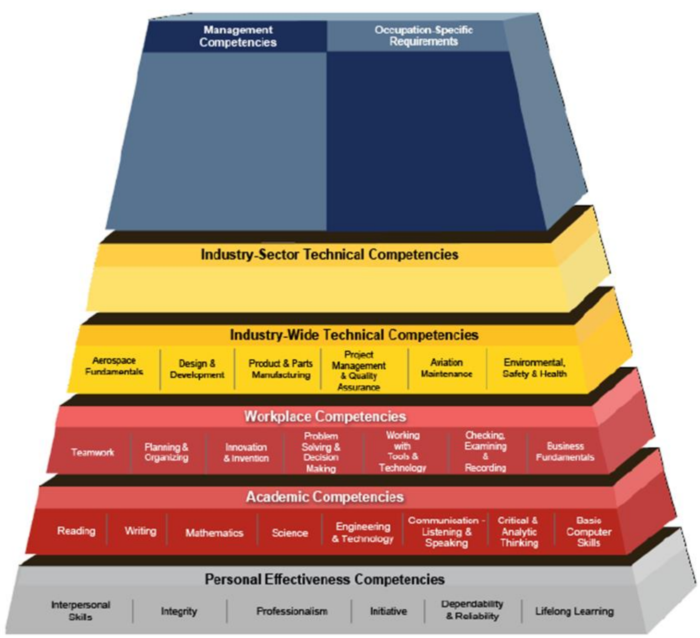

Figure 1. U.S. Dept. of Labor aerospace competency model (Note: This figure illustrates the aerospace industry's desired workplace and workforce interpersonal and technical competencies. Source: U.S. Dept. of Labor, Employment and Training Administration (2018). Aerospace industry competency model. Tier 3 Workplace competencies)

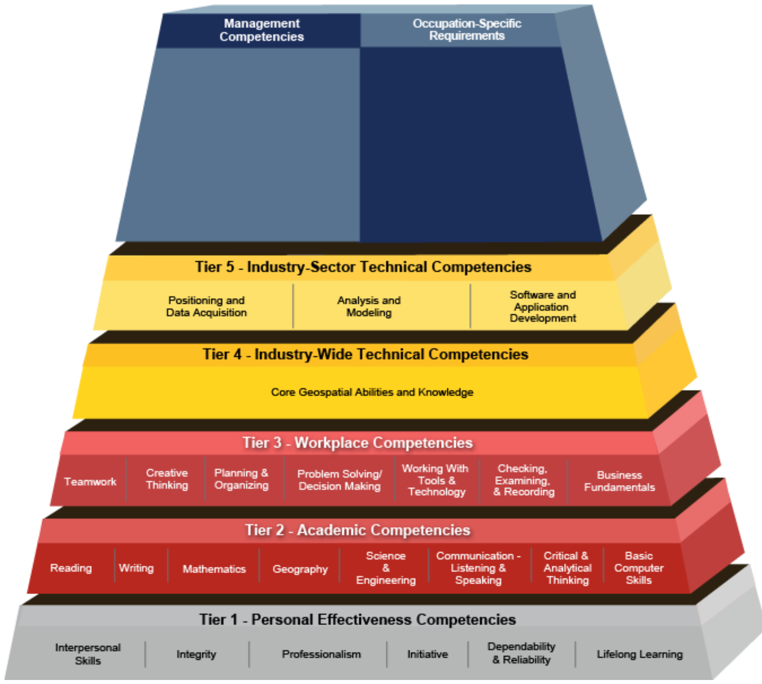

Figure 2. U.S. Department of Labor geospatial competency model. (Note: This figure illustrates the geospatial industry's desired workplace and workforce interpersonal and technical competencies. Source: U.S. Dept. of Labor, Employment and Training Administration (2018). geospatial industry competency model. Tier 4 Workplace competencies)

The workforce survey results from phase 3 found the four most selected competencies to be Safety and Quality Focus (81%), Technically and Mechanically Proficiency (64%), and Operations Acumen (54%), and Data Collection/Processing Acumen (43%). Participant's survey comments further suggest a significant importance for responsible and ethical behavior, leadership abilities, and an entrepreneurial mindset by UAS professionals These findings are supported by Figure 3, which illustrates the number of times a competency was selected by survey respondents, while Table 3 illustrates the mean ranking of each competency. For example, from Figure 3 we find that 98 survey participants selected Operations Acumen as a top three competency, making it the third most selected competency. However, from Table 3 we see that the mean rank of Operations Acumen was fifth - meaning those that selected Operations Acumen generally ranked it lower in importance than the other selected competencies.

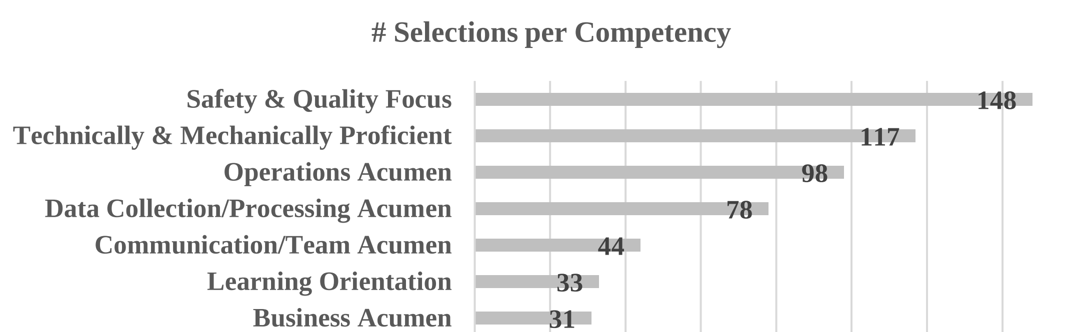

Figure 3. Number of Selections per Competency from UAS Workforce Survey

Table 3.
Mean Ranking of Selected Competencies from UAS Workforce Survey

Selected Competency	Mean Rank
Safety & Quality Focus	1.56
Technically & Mechanically Proficient	2.11
Data Collection/Processing Acumen	2.12
Learning Orientation	2.15
Operations Acumen	2.16
Communication/Team Acumen	2.27
Business Acumen	2.32

One of the distinguishing attributes developed at the foundational level in the academic context but is refined and sharpened throughout one's own professional service is the ability to make sound ethical decisions while delivering operational excellence in a high-risk environment. Oliver, Collin, Burns, & Nicholas (2006) noted the importance of teaching/learning leadership and ethical decision-making skills in the context of real-life scenarios and impact. The UAS students learn about work in a profession that constantly manages risk—even in the academic setting. From the time they begin their course of study, the students own experience should demonstrate that their actions have consequences and are meaningful. This provides immediate relevance to the competencies developed by the students. In general, competencies have been defined as combined and integrated components of knowledge, skills, and attitudes. As such competencies are changeable, learnable and attainable through experience, training or coaching (Man, Lau, & Chan, 2002; Volery, Mueller, & Von Siemens, 2015). In this context, various competencies arise when subject matter excellence needs of the UAS program are overlaid with the literature regarding the knowledge, skills, and abilities needed for the success of the aviation industry.

The job description text mining results found 28 stem words with counts greater than 40 (Figure 4). From these 28 stem words emerged 21 trigrams with counts greater than four. Researchers reviewed these results and performed a content analyses to categorize the content and develop themes. The text mining results generally align with the findings from the workforce survey and the previous quantitative research. The following eight themes emerged from this text mining exercise.

1. Safety Risk Management
2. Operational Skills
3. Technical Expertise
4. Certification/Training
5. Problem Solving
6. Data Gathering/Analytics
7. Communication Skills
8. Experience

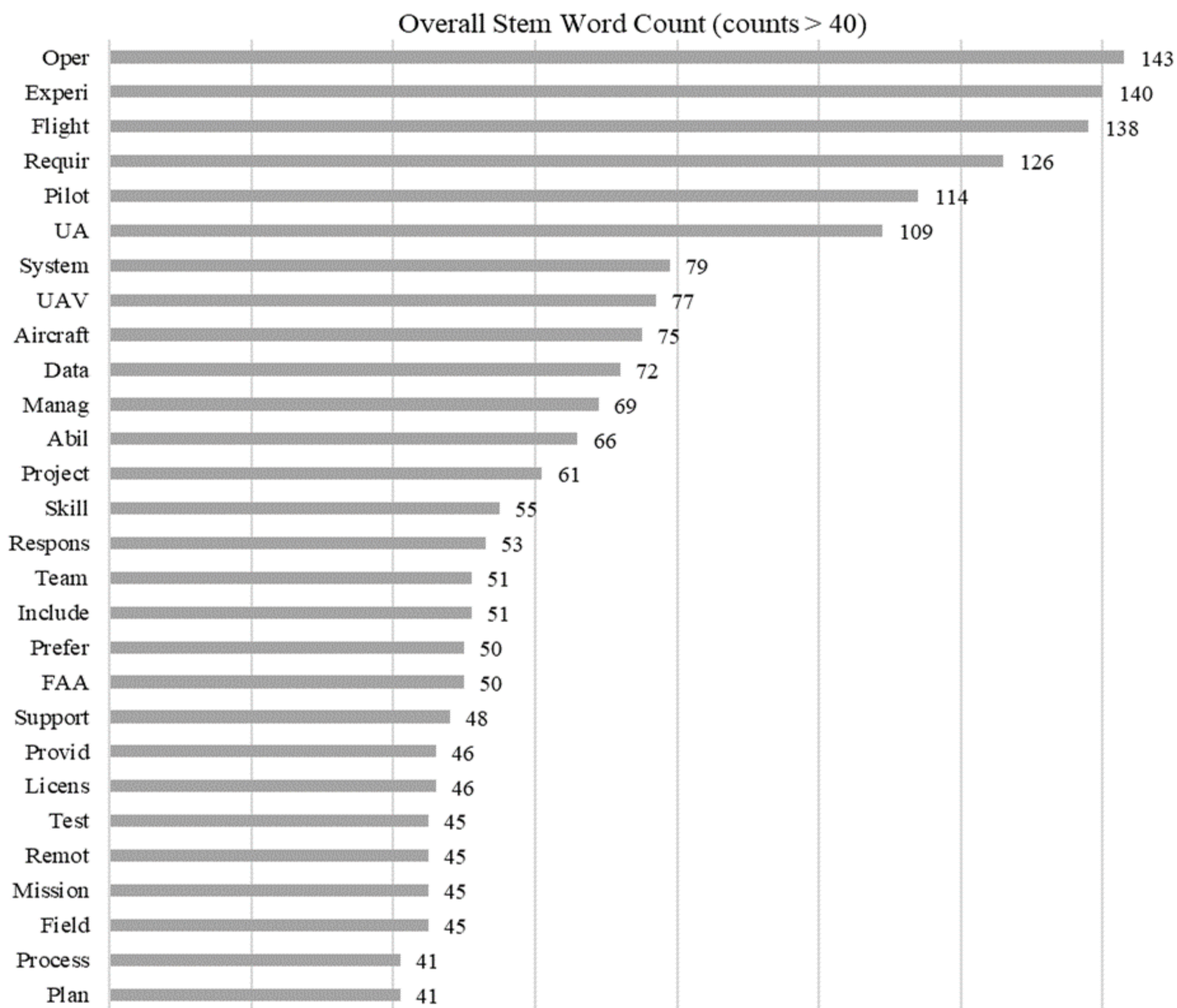

Figure 4. Text Mining Stem Word Counts from UAS Job Postings

The UAS Competency Learning Model

This study of the UAS ecosystem and a review of the other aviation related disciplines such as flight, technology, and management, found the emergence of the following six UAS competencies: Leadership, Technical Excellence, Safety and Ethics, Analytical Thinking, Teamwork, and Entrepreneurship. Figure 5 illustrates the contributory nature of UAS competencies toward the development of a theoretical UAS Competency Learning Model. Ideally, a UAS graduate will exemplify each of these six competencies at a minimum.

Figure 5. Theoretical UAS Competency Learning Model

Leadership

A review of the literature and these research results confirmed that the aviation community continues to highly desire graduates who possess the maturity and ability to lead others. More specifically, interviews and discussions with IAB members and other UAS industry leaders found leadership is a key competency sought after in a UAS graduate. Leadership is a multidimensional competency. As a person's leadership matures, they gain more holistic views and become more adept at cross-functional interactions. This competency houses the skills to adapt to different levels of an organization: the operational/functional level, the business level, the corporate level, or the industry/sector level. Singer (2014) identifies critical performance capabilities for an innovative leader to master different stages of innovation. These include (1) Ideation or gathering promising ideas, (2) Building a team, (3) Refining ideas with the teams, (4) Estimating the cost and values of the proposed idea, (5) Reviewing the ideas against predefined criteria and objectives, (6) Identifying the best ideas for likely funding and seeking budgets for implementation, and (7) Delivering a finished product on the ideas put forth while developing the ability to see larger pictures, and understand how one set of problems and solutions fit into larger problems and solutions. Intrinsically, leadership can also be about leading one's self even when performing an individual task, where sound planning, communication, task execution and integrity remain paramount in the context of the hazardous aviation environment.

As the leadership elements identified in this review began to saturate and repeat, researchers returned to the U.S. Department of Labor aerospace model (Figure 1). This review identified key elements of leadership competency outcomes targeted by the UAS curriculum. The Leadership learning outcomes selected were distilled into the following five categories:

1. Fostering actions towards achieving vision, mission, and goals of a project or activity.
2. Facilitating group processes.
3. Utilizing situation, context, and cultural aspects of organizations effectively.
4. Demonstrates the knowledge, skills and abilities to manage, lead and empower others to efficiently address group needs and objectives.
5. Manages and resolves conflicts and disagreements in a constructive manner.

When these leadership elements are examined across the other five UAS program competencies (Technical Excellence, Safety and Ethics, Analytical Thinking, Teamwork, Entrepreneurship), the Leadership competency emerges as an important component of each competency. A goal of a UAS degree program is to produce graduates that are at least equal in caliber of the graduates from other traditional aviation programs – graduates who are highly valued as leaders across the aviation and aerospace industry.

Technical Excellence

Technical excellence was the second most selected competency by survey participants and #2 in mean rank. This finding was further supported associated words in the text mining results and interviews with industry representatives. An Unmanned Aerial System is an extremely complex machine comprised of integrated hardware and software that must work together as a system. The UAS student must demonstrate competency in understanding how UAS platforms operate and combine this with a knowledge of accepted industry standards, safety management, regulatory policy, and customer requirements. Furthermore, understanding the significance of the sensor payload on a UAS platform in terms of what it can and cannot do, make Technical Excellence a crucial competency for the UAS graduate. What sets the UAS graduate apart from other aviation programs is that not only must they have a solid aviation knowledge but they must also demonstrate an understanding in one or several areas of what constitutes the Digital Transformation in our current economy; i.e. Edge Based Computing, Cloud Computing, Artificial Intelligence, and Data Science (Siebel, 2019). For the UAS student, strong background knowledge is needed in the geospatial and data realm, as the majority of UAS market growth is related to the sensor payload that gathers some form of data. While a UAS program will not develop an expert in data science, graduates should be familiar with the fundamentals of the emerging technology, which includes not only its capabilities but also its limitations.

Subtitle D in the 2018 FAA Reauthorization Bill called for development of UAS Centers of Excellence, thus establishing the need to produce UAS operators that are trained to operate UAS platforms safely and efficiently (FAA, 2018). Although the UAS industry is new, it is growing at a rapid rate and often demonstrates itself as a disruptive technology. This technological growth often outpaces the evolution of public policies and challenges socio-economic norms. These factors suggest that a UAS program must be structured to not only meet the current needs of the UAS ecosystem, but also remain flexible and agile to adjust for future changes in the UAS industry.

The pyramid-based skill set development put forth by the U.S. Department of Labor Aerospace and Geospatial Competency Models (U.S. DOL, 2018a, U.S. DOL, 2018b) were utilized as a basis for performance rubric development. Other related rubrics for assessing technical performance also correspond to related learning objective development for subject matter excellence (AACU, 2009; Lercel, et. al, 2015; Roffeypark, 2018; State of Washington, 2018). These sources provide cross-validation of common performance themes most salient to the outcome targets for the UAS program. Thus, the outcomes for Technical Excellence follow:

1. Implements and manages UAS technology in accordance with applicable laws, regulations, standards, and accepted means and successfully completes appropriate UAS certifications.
2. Makes sound decisions and solves problems.
3. Demonstrates appropriate business acumen that achieves joint optimization of business benefits and technical excellence.
4. UAS airmanship and airworthiness.
5. Operates and applies technology in a manner that meets certification and industry standards, ensures safety, and meets customer expectations.

Safety and Ethics

Safety/Quality was the most selected competency by survey participants with a #1 mean ranking. Text mining results further supported the importance of safety. A review of the literature along with interview data found that ethical behavior is strongly associated with safety and remains a steadfast requirement among aviation professionals. In the context of a UAS professional, ethical behavior goes beyond the traditional pillars of aviation safety because of the discreet operational capabilities of UAS along with the collection of often sensitive data.

In a sense, ethical behavior and integrity competencies relate most immediately to airworthiness in the most profound way. Airworthiness, operational safety, quality and reliability ultimately come down to choices by the individuals (Patankar et al, 2005; Oderman, 2002). Ethical behavior should be instilled in a UAS operator in the same way it would for an individual working within a manned aviation organization, such as an airline or airframe manufacturer. Society continues to cast a wary eye on UAS, and it remains a disruptive technology often viewed with great trepidation by those in manned aviation and the general public. Being grounded in the concepts of ethics is a competency in the UAS program that should not be glazed over, nor ignored. In a broader sense this competency area is intertwined with several other aviation competencies. UAS graduates must incorporate ethics and integrity into every decision, identifying right from wrong and choosing to follow the right path. If one part of ethics and integrity is doing something the right way even when nobody is around, similarly the aviation professional must be willing to take a professional stand if something is not safe (Patankar et al, 2005; Oderman, 2002).

The authors reviewed associated ethics and integrity performance rubrics from prevailing academic literature (AACU, 2009; Texas A&M, 2018) to identify observable metrics at the individual learner level that best map to the UAS program curriculum. A guiding definition was distilled from this review regarding ethics and integrity as it relates to UAS programmatic and industry expectations: a reasoning about right and wrong human conduct. It requires a student be able to assess their own ethical values and the social context of problems, recognize ethical issues in a variety of settings, think about how different ethical perspectives might be applied to ethical dilemmas and consider the ramifications of alternative actions. The guiding definition of integrity was similarly derived: adherence to moral principles, honesty, truthfulness, uprightness, sincerity and making choices based on your belief of what is right. Thus, the outcomes for Safety and Ethics are as follows:

1. Recognize ethical issues.
2. Personal Responsibility.
3. Demonstrate knowledge and understanding of UAS human factors.
4. Understanding current and proposed UAS regulatory framework and its intent.
5. Knowledge and understanding of Safety and Risk Management principles and the ability to develop appropriate policies and processes that support these principles.

Analytical Thinking

Data analytics/processing acumen was the fourth most selected competency but #3 in mean rank. Similarly, data acquisition, processing, and analysis remained a dominant theme in the text mining results. Analytical competency is tightly coupled to making sense of the data, making effective decisions, and solving problems; therefore, analytical thinking is a crucial skill across the realm of aviation and key to the success of a UAS graduate. Analytical thinking is demonstrated by the ability to effectively communicate in written, graphics-based and verbal forms. The ability to critically analyze and interpret data gathered by UAS sensors also presents itself as a needed skill for the UAS graduate. The need to effectively convey critical and analytical information in such forms is well documented (ICAO, 2016). Below we discuss the two components of analytical thinking important for UAS professionals: (1) Decision Making and Problem Solving and (2) Data Analysis.

Decision Making and Problem Solving

Effective analytical thinking also lends itself to proper decision-making skills. Scholars indicate there are two broad categories of decision-making theory: normative and descriptive (Peterson, 2009). Normative decision-making theory is one that describes how decisions ought to be accomplished. In contrast, descriptive decision-making theory pertains to how the decision was accomplished, in a post-hoc fashion. Theories have led to the development of a range of training and practices to improve the decision-making process. Many of these use the 'classical decision method' within the normative category which involves the rational analysis of options in order to make the best choice. In simple terms, this method of decision-making can be described as a step by step process which comes in different variations. One example is identifying the problem, gathering information, identifying alternatives, weighing the evidence, choosing, acting, and reviewing the results (Royal Institute of Technology, 1994). Proactive and effective decision-making can provide a competitive edge to organizations, reduce risks and liability, and improve critical thinking and situational awareness (Concordia, 2017). Variations of step-by-step decision-making processes can be taught, evaluated, and utilized in discipline-specific contexts.

The FAA (2020f) defines Aeronautical Decision Making (ADM) as:

> A systematic approach to the mental process used by pilots to consistently determine the best course of action in response to a given set of circumstances. It is what a pilot intends to do based on the latest available information (p. 2-2).

The foundation of the assessment for the decision-making competence is Bloom's Taxonomy to include psychomotor, cognitive, affective, and interpersonal levels (Bloom, 1956; Callister, 2017). Ideally, Bloom's taxonomy may be used to describe instructional objectives and conduct objectives-based assessments on the UAS students' achievement for aligning curriculum and assessment. Bloom's taxonomy and the decision-making literature suggest the following sub-level competencies for a UAS program:

- Applies appropriate decision-making processes.
- Demonstrates the ability to address complex issues.

Graduates of a UAS ideally will demonstrate proficiency in analytical thinking and decision-making which will allow them to understand and solve complex problems, including those related to aviation safety, advanced technology, and a wide range of technical matters, as well as abstract concepts.

Data Analysis

Critical, logical, and analytical thought are necessary data science for the UAS graduate. Data, especially geospatial data, is in almost every part of UAS operations ranging from mission planning, execution, and post-flight record keeping. The UAS graduate must also be able to logically and effectively gather, process, and analyze data gathered by UAS sensors. The UAS graduate is a significant participant in the information age economy, and therefore must be able to demonstrate all the needed skills associated with Data Science (Rasheva-Yordanova and Nikolova, 2018).

By definition, a student versed in analytical thinking within Data Science must be able to identify and define problems, extract key information, develop workable solutions, and test and verify workable solutions to problems. The Analytical Thinking learning outcomes selected were distilled into four categories:

1. Demonstrates the ability to access, interpret, and appropriately apply technology, data and technical information.
2. Demonstrates the knowledge, skills, and abilities to focus and think clearly while under pressure.
3. Uses an action-oriented and objective approach to problem solving.
4. Demonstrates knowledge, skills, and abilities that are required across the entire UAS workflow, which includes data collection, data analyses, and interpreting data.

Teamwork

When preparing the next generation of aviation professionals, it is important to consider that teamwork provides a redundant system that could have a positive impact on individual and team performance as well as aviation safety and efficiency, critical factors to the aviation industry. This research suggests UAS professionals should have the competence to work as members of a team to effectively convert team inputs into targeted outcomes. Effective teamwork requires one to possess key disciplinary skills, among them are the ability to effectively communicate, and participate in key decision making and problem-solving activities.

Teamwork is a competence that should be taught and practiced (Brannick, Prince, & Salas, 2005). To be successful in today's professional flight environment, students need to develop knowledge, skills, and abilities to work interdependently, adaptively, cooperatively, and dynamically toward shared and valued goals. In addition, they should develop the knowledge, skills, and abilities to guide, coordinate, and facilitate teamwork activities across cultural boundaries and as the team leader. With regards to Teamwork, suggested student learning outcomes for graduates of a UAS Program are as follows:

1. Facilitates the Contributions of Team Members, Responds to Conflict (Conflict management).
2. Individual Contributions Inside and Outside of Team Meetings (Task development and completion).
3. Develop skills to immerse with others from different cultures.
4. Understand and apply crew resource management (CRM) concepts to UAS operations.

Entrepreneurship

This research found the UAS ecosystem is comprised of mainly small start-up companies, which includes anything from software, to sensors, to airframes; or larger companies looking to integrate UAS technologies into their existing business operations – seeking the potential value that UAS may add to their work product. A little over 57% of survey respondents work in organizations with 10 or fewer employees and 49% have been in business less than six years. Group discussions and interviews confirmed that a majority of UAS companies describe themselves as a "start-up," engaged in some aspect of "technology or market development," and have "evolved or pivoted" business strategies multiple times. This innovative and evolving environment requires graduates who have an entrepreneurial skill set with the ability to "think outside the box" and develop innovative solutions, stay motived and resilient. Multiple authors have stated that the entrepreneur is central to the success of small and medium sized business (Man et al., 2002; Man, Lau, & Snape, 2008). These claims offer a positive perspective for supporting (aspiring) entrepreneurs as most authors agree that competencies are not fixed traits but can be developed and learned through experience and training (Wagener, Gorgievski, & Rijsdijk, 2010).

Successful entrepreneurs possess an orientation towards learning, searching for new knowledge and developing skills that help improve themselves. It refers to participating in training and development activities, seeking and following up on new opportunities, knowing where to find relevant information and being interested in new methods and techniques that are relevant for their profession (Lans, Hulsink, Baert, & Mulder, 2008).

Economic forecasts estimate that over the next decade the UAS market will total $88.3 billion. UAS technologies and markets will continue to evolve at an ever-increasing pace (Goldman, 2017; Teal, 2019). Venture capitalists and companies like Intel, Qualcomm, Microsoft, and Apple invested over $455 million into drone startups in 2018. U.S. start-ups received 67% of this total, enabling them to take the lead in drone analytics (Teal, 2019).

These optimistic market forecasts along the findings from this research suggest that graduates with an entrepreneurial skill set may be best prepared for long term success; therefore, the authors propose the following Entrepreneurship learning outcomes:

1. Adaptability/Innovation: demonstrate an ability to engage in critical thinking by analyzing situations and constructing and selecting viable solutions to solve problems.
2. Self-efficacy: identify and assess individual and group strengths and weaknesses and believe in one's ability to influence the course of events, despite uncertainty, setbacks and temporary failures.
3. Learning through experience and coping with ambiguity and risk.
4. Creativity and Vision: develop ideas and opportunities that may create value, solutions, or improvements and develop a vision that turns these ideas into action.
5. Initiative and Action: initiate processes that create value or address challenges. Act and work independently to achieve goals, stick to intentions and carry out planned tasks.

Conclusions

A review of the literature found little data regarding the specific competencies employers seek in UAS professionals. This research found a preponderance of the UAS literature focuses on the knowledge that may be required of a remote pilot to operate a UAS legally and safely, namely basing training and curriculum toward the ultimate goal of the student pilot earning their FAA Part 107 remote pilot certificate. A preliminary review of UAS student internships and post-graduation plans demonstrate active growth in the UAS industry.

Although this research attempted to include many stakeholders in the UAS industry, the 220 research participants in this study are but a small percentage of an industry that continues to evolve at a break neck pace with thousands of participants in myriad roles. The UAS Competency Learning Model presented here provides a solid background on which to create a UAS program capable of developing a high level of practitioner skills. Despite this foundation of competencies to build upon, it should be noted that technology and regulations continue to develop and it is anticipated that future competencies of UAS graduates will continue to morph; therefore, it is vital that research continues in this area. UAS programs, curriculum, and training models built around these competencies should be designed to be adaptable in changes within the industry as technology and regulations continue to evolve.

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Bias and Trends in Student Evaluations in Online Higher Education Settings

Cheryl Lynn Marcham
Embry-Riddle Aeronautical University

Ann Marie Ade
Embry-Riddle Aeronautical University

Patti Clark
Embry-Riddle Aeronautical University

James Marion
Embry-Riddle Aeronautical University

End-of course evaluations have been frequently used to assess teaching effectiveness and influence critical decisions about faculty contract renewal, future course assignment, tenure and promotion in higher education. This quantitative study sought to determine whether there are differences in student perceptions of faculty performance based on gender or faculty status (full-time vs. adjunct) in an online higher education environment. It also sought to answer these questions: 1) Do adjunct faculty tend to grade more leniently than full time faculty, and as such, do adjunct faculty receive higher evaluation ratings than full time faculty, who may be more stringent in grading? 2) Do student evaluation scores differ depending on the course being evaluated? 3) Does gender or faculty status impact student response rates? Survey responses from a total of 683 sections associated with 24 courses were analyzed from the March 2018 to January 2019 timeframe. Due to the broad range of class sizes and differences between faculty characteristics, the variances for each comparison sample were observed to be significantly different using Levene's test for equal variances. Thus, the Mann-Whitney test for two variables and the Kruskal-Wallis test for evaluation of significant difference between more than two variables were used on the data. While other literature and personal anecdotes may indicate that gender bias exists, this study did not indicate that gender bias is occurring in online higher education courses taught for the time period studied, suggesting gender neutrality.

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The use of student evaluations is ubiquitous at institutions of higher education, and often, important decisions are made based on student evaluation data. For example, administrators use teaching evaluations for annual review, promotion, tenure, and reappointment decisions. Department heads may consider results from evaluations to decide whether to keep a course or course content in the curriculum or to change it. Because the results from student evaluations can have such high stakes, it is important that we understand the limitations of any potential bias that might occur from a variety of sources or conditions, or bias towards a particular category of recipient.

Gender Influences

Previous research has illustrated that gender differences have historically been prevalent in student end-of-course and instructor evaluations in traditional brick and mortar settings. In 1989, a study of 9,005 student evaluations found that female professors, overall, had lower ratings than males for teacher effectiveness, academic competence, sensitivity to student needs, and overall performance; these differences held even while controlling for a number of variables such as students' sex, GPA, expected grade, discipline, and course size (Andersen & Miller, 1997; Sidanius & Crane, 1989). In 1991, Statham, Richardson, and Cook reported that there were differences in gender expectations for university instructors, and as a result, differences in how instructors were evaluated. For instance, the more classroom time a woman professor spent in presenting material, the lower her likability ratings, but the reverse was true for the male professors (Statham, Richardson, & Cook, 1991). Checking students' understanding and soliciting their input also enhanced the women's competence ratings but had a strong negative impact on both competence and likability ratings for men (Statham, Richardson, & Cook, 1991).

A gender bias can still be found in more current student evaluations of traditional university classroom instructors. A study of 19,952 student evaluations of university faculty at the School of Business and Economics of Maastricht University in the Netherlands over the period 2009-2013 found that, on average, female instructors systematically received a score 37 percentage points lower than male instructors, a bias primarily driven by male students' evaluations (Mengel, Sauermann, & Zolitz, 2018). Student evaluation data from the University of Oregon consisting of over 36,000 data sets collected from 2010 to 2016 were evaluated by Ancell and Wu (2017), who found that female instructors received course evaluation scores, on average, 0.0578 points lower than male instructors.

In some cases, the difference in ratings between male and female instructors has been attributed to students having different expectations for male versus female instructors. As described earlier Statham, Richardson, and Cook (1991) showed that historically, and in a traditional classroom setting, differences in gender expectations resulted in differences in how instructors were evaluated. This difference is consistent with the role congruity theory (Eagly & Karau, 2002) where students may expect female instructors to behave according to female gender stereotypes and male instructors to behave according to male gender stereotypes, but still evaluate overall teaching competence for all instructors according to the characteristics of the stereotypical male professor (Boring, 2017; Kierstead, D'Agostino, & Dill., 1988; Basow, Phelan, & Capostosto, 2006; MacNell, Driscoll, & Hunt 2015). These gender stereotypes are still found in current studies. Boring evaluated 20,197 student evaluation scores over five academic years from traditional classroom courses and found that male students gave significantly higher overall satisfaction scores to male professors than to female professors. Boring also found that, in this study, a male professor's expected excellent overall satisfaction score was approximately 20% higher than a female professor's expected excellent overall satisfaction score, even though students performed equally well on final exams whether their professor was a man or a woman, suggesting no difference in actual teaching effectiveness. Thus, Boring posited that differences in teaching skills were not driving the gender differences in evaluations. In 2019, in a study of more than 523,000 student evaluations with more than 3,100 instructors, Fan et al. found that male students gave lower scores to female instructors regardless of the cultural backgrounds of either student or instructor. Clearly, there is an abundance of information indicating that gender bias against female instructors in student evaluations may still be occurring, at least in the traditional classroom setting.

Course subject may also have an impact on overall evaluation scores. Beran and Violato (2005) found that evaluations for courses in social sciences received significantly higher ratings than courses in natural sciences. Uttl and Smibert (2017) found that evaluations for quantitative classes like those in math received much lower average class summary ratings than non-quantitative classes such as those in English, history, or psychology. Related to this issue are studies that have shown that gender bias in student evaluations may also be more significant for some fields of study than others (Rosen, 2017). Fan et al. (2019) found that where there are larger proportions of female teachers, such as in the Arts and Social Sciences, there is less gender bias in student evaluations of teaching. Conversely, in technical and scientific areas of study, more gender bias may be prevalent.

With the increasing number of university courses moving to an online environment, one question that arises is whether gender bias becomes less predominant in a distributed environment. Online higher education has been promoted as an *equalizer* that breaks down the access barrier, and not only provides access for students from diverse cultures, but from diverse situations and economies all over the world (Black, Bissessar, & Boolaky, 2019). Cohen and Ellis, in 2008, posited that asynchronous learning networks (ALN) offered the potential to create a gender neutral communication environment. However, Mitchell and Martin (2018) report that when comparing evaluations for instructors teaching identical online courses, the language students used in evaluating a male professor was significantly different than the language used in evaluating a female instructor, and the students gave higher ordinal scores in the teaching evaluation to a male instructor than to a female instructor, even for questions specific to the course, not to the instructor. MacNell et al. (2015) found similar results in that students rated the instructors they perceived to be female lower than those they perceived to be male, regardless of teaching quality or actual gender of the instructor. These differences in student ratings were not a result of gendered behavior on the part of the instructors, but of actual bias and differing expectations on the part of the students. For example, when male and female instructors posted grades after two days as a male, this was considered by students to be a 4.35 out of 5 level of promptness, but when the same two instructors posted grades within the same time frame as a female, it was considered to be a 3.55 out of 5 level of promptness (Macnell et al., 2015).

However, both of these studies have limited sample sizes, as one involved only two instructors during a single term and the other involved only 43 students in a single 5-week summer class at a large public institution with over 20,000 students. Boring, Ottoboni, and Stark performed nonparametric statistical evaluation of over 23,00 evaluations from both the Boring study (originally published in 2015) and the Macnell, Driscoll & Hunt study, and confirmed bias against female instructors "by an amount that is large and statistically significant" (Boring et al., 2016b, para. 1). These researchers found that instructors whom students believed were male received significantly higher average ratings than those whom students believed were female (Boring et al., 2016b).

Grade Influences

Another issue of concern is when institutions focus on student evaluation data to make faculty review, promotion, tenure, and reappointment decisions; many instructors may choose to please the students with reduced scrutiny of assignments and higher grades to ensure high evaluation rates. Johnson (2003) argued that the onset of the importance given to student evaluations has brought about rampant grade inflation, as professors realized they could achieve better evaluation scores through easier grading. Stroebe (2016) continued this work, showing that that while the grade point average at colleges and universities has increased for decades, the amount of time students devote to their studies has continuously decreased. Stroebe (2016) argues that this grade inflation is:

> …encouraged by the practice of university administrators to base important personnel decisions on student evaluations of teaching. Grading leniency creates strong incentives for instructors to teach in ways that would result in good student evaluations. Because many instructors believe that the average student prefers courses that are entertaining, require little work, and result in high grades, they feel under pressure to conform to those expectations. (p. 800)

A 2016 survey of faculty members by the American Association of University Professors, revealed that 67 percent concurred that student evaluations put upward pressure on grading practices (Doerer, 2019). Ancell and Wu (2017) found that for each one point in increase in the GPA of a class led to between a 0.182 and 0.319 point increase in the instructor's evaluation score. Braga, Paccagnella, and Pellizzari (2014) found that teachers of classes that are associated with higher grades received better evaluations from their students. Numerous additional researchers have confirmed that instructor ratings have been found to correlate with student grades in the course (Adams & Umbach, 2012; Crumbley and Reichelt, 2009; Isely and Singh, 2005; Marsh 2007; Carrell & West, 2010; Krautmann & Sander, 1999; Weinberg, Hashimoto, & Fleisher, 2009; Boring et al., 2016b). Connected to this correlation is the concern that numerous studies that show that adjunct faculty in higher education institutions assign higher grades than full-time faculty (Reynolds, 2015; Cavanaugh, 2006; Kezim, Pariseau, & Quinn, 2005; Lippmann, Bulanda, & Wagenaar, 2009; Sonner, 2000). In fact, Boring et al. (2016a) state that the evaluation process contributes to grade inflation.

Limitations of the Student Evaluation Process

Student evaluations are often given a high priority even though several studies show that there is no direct correlation between student evaluations and teaching effectiveness or student learning. Linse (2017) published guidelines for the use and interpretation of student ratings data. In these guidelines, Linse emphasizes that student ratings are student perception data, not faculty evaluations, and that student ratings are not measures of student learning. Doerer (2019) opines that often, students are treated as customers, and their evaluations are more a metric of student satisfaction, not academic progress. Boring et al.'s (2016b) statistical analyses of more than 23,000 evaluations of 379 instructors by 4,423 students concluded that the association between student evaluations and teaching effectiveness was weak and not statistically significant. To quote Flaherty on the issue, students' teaching evaluations, "measure students' gender biases better than they measure the instructor's teaching effectiveness" (2016, para. 1). Boring et al. (2016a) argue that the evaluations are not strongly associated with learning outcomes, and as such, evaluating ratings are "at best, weakly associated with student performance" (para. 5).

Canadian researchers conducted a meta-analysis of 97 studies that revealed that students do not learn more from professors with higher student evaluation ratings, and such ratings are unrelated to student learning. Further, research by Braga, Paccagnella, and Pellizzari (2014) found that teachers who were more effective in promoting future performance receive worse evaluations from their students, indicating that evaluation scores are not related to teaching effectiveness. In fact, a 2016 meta-analysis of 51 articles containing 97 multi-section studies on student evaluations of teaching (SET) concluded that:

> Despite more than 75 years of sustained effort, there is presently no evidence supporting the widespread belief that students learn more from professors who receive higher SET ratings. If anything, the latest large sample studies show that students who were taught by highly rated professors in prerequisites perform more poorly in follow up courses. (Uttl, White, & Gonzalez, 2017, p. 40)

Because of the potential for bias, and because there is not a documentable connection between student evaluations and learning, or between student evaluations and teaching effectiveness, several institutions have abandoned or restructured the student evaluation process. In Canada, the Ryerson University Faculty Association argued that because of well-documented bias in student evaluations, they shouldn't be used for personnel decisions (Doerer, 2019). In August, 2018, Ryerson University was ordered by an arbitrator to amend the faculty collective bargaining agreement to ensure that faculty course survey results are not used to measure teaching effectiveness for promotion or tenure (*Ryerson University v. Ryerson Faculty Association*, 2018). In September, 2018, The University of Southern California Academic Senate concluded that since "research on student evaluations show that results are not correlated with learning outcomes or other valid measures of teaching effectiveness," and since these evaluations are "prone to systematic bias against women and…faculty of color," that there was a "need for a more meaningful review of teaching than student evaluations provide" (University of Southern California Academic Senate, 2018, para. 4-5). In March 2019, the University of Oregon Office of the Provost posted that it was working with the University Senate to revise the teaching evaluation system because:

> Recent research suggests that student ratings may not accurately reflect the quality of teaching due to biases and other factors. The University of Oregon's own assessment of student course evaluation ratings have corroborated these findings. The Association of American Universities (AAU) and other universities around the globe from University of Colorado, Boulder to University College London, England have argued that it is time for universities' practices regarding teaching excellence and evaluation to align with their policies. As such, the University of Oregon seeks to develop a holistic new teaching evaluation system that does more than simply replace problematic evaluation instruments so that we can help the UO community more effectively define, develop, evaluate, and reward teaching excellence. (para. 1-2)

After performing a comprehensive meta-analysis of 97 studies, Uttl, White, and Gonzalez (2016) suggested that because there was little to no significant correlation found between evaluation rating and learning, "institutions focused on student learning and career success may want to abandon SET ratings as a measure of faculty's teaching effectiveness" (para.1).

Therefore, given the current reliance on end-of-course evaluations to assess faculty teaching effectiveness, contract renewal, tenure, and promotion decisions, an assessment of potential bias in student evaluations for faculty at a regionally accredited online university was undertaken. This study sought to determine whether there are differences in the student perceptions of faculty performance based on gender or faculty status (full-time vs. adjunct). This study also sought to evaluate such questions as:

1. Do adjunct faculty tend to grade more leniently than full time faculty, and as such, do adjunct faculty receive higher evaluation ratings than full time faculty, who may be more stringent in grading?
2. Do student evaluation scores differ depending on the course being evaluated (i.e., if a course is poorly designed or particularly difficult, will that result in overall lower instructor evaluation scores, regardless of the instructor presenting the course)?
3. Does gender or faculty status impact student response rates?

The overall purpose was to identify potential bias that may affect future course, promotion or tenure decisions, based in part on current end-of-course survey responses, and whether there are any trends that can predict evaluation results. Given the nature of the focused curriculum (aviation/aerospace) and the predominance of male faculty and students at this university and within the target industry, any biases toward female faculty, or towards full time faculty who will not succumb to grade inflation pressure, may harm the potential of female or full time faculty to progress through the ranks of the university.

Methodology

The online campus for this study provides courses that are structured such that a master course outline and a master course template are provided to both full time and adjunct faculty assigned to teaching the course. Instructors are advised that no changes are to be made to the course template, assignments, syllabus, or rubric. Therefore, the material presented, the manner in which it is presented, the assignments and assessments, as well as the grading structure are all consistent between instructors. Instructors are, however, encouraged to supplement the online course, and are expected to post personal biographical information, participate in weekly discussion boards, and regularly post announcements to engage the students.

A total of 683 sections associated with 24 courses taught in the online campus were selected from historical class records from the period of March 2018 to January 2019. Courses selected were those that were frequently taught by multiple instructors, had not been updated or changed during the study period, and were from a range of technical and general courses, including math, economics, aviation, English, research, and occupational safety topics. Student end-of-course survey responses, which are not required to be completed in order to obtain a final grade or any other service from the university, were collected for these course sections. By the very design of the end-of-course survey process, no personally identifiable data is collected about the student respondents. Grade distributions for each section of the course offered during the time frame as well as the data relating to the gender and employment status of the faculty member were collected and coded by the Office of Institutional Research to protect the identities of all participants, both faculty and students in the selected sections of courses for analysis. The categories of data collected from each course included the following:

- Course number and title
- Full-time/part-time instructor status
- Instructor gender
- End-of-course evaluation question response rates
- Class grade point average (GPA) per course
- End-of-course evaluation question scores for the following questions:
    - The instructor exhibited expertise in the course subject matter
    - My overall impression of the instructor is positive
    - The instructor provided meaningful and timely feedback on my assignments and progress

End-of-course evaluation scores are on a Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). All data collected can be available to other researchers upon request.

Based on the data collected, the following research questions were evaluated:

1. Is there a significant difference in GPA between courses?
2. Is there a significant difference in class GPA between male and female instructors for all classes?
3. Is there a significant difference in class GPA between full time and part time instructors for all classes?
4. Is there a significant difference in end-of-course evaluation question scores between male and female instructors?
5. Is there a significant difference in end-of-course evaluation question scores between full time and part time instructors?
6. Is there a significant difference in end-of-course evaluation question scores between

courses?

7. Is there a relationship between course GPA outcomes and student evaluation response scores?
8. Is there a significant difference in end-of-course evaluation question response rates between faculty genders?
9. Is there a significant difference in end-of-course evaluation response rates between full-time and part-time faculty?

All research questions except for research question 7 involved tests of significant differences for one or more variables. The raw data for each research question was evaluated for equality of variances using Levene's test for equal variances. Due to broad range of class sizes and differences between the number of male versus female and full time versus part time faculty, the variances for each comparison sample were observed to be significantly different. All tests of significance therefore used the Mann-Whitney test for two variables, and the Kruskal-Wallis test for evaluation of significant difference between more than two variables.

Table 1
Faculty Composition and Class Size Information

Faculty Status	Faculty Gender	Mean Class Size	Class Size Standard Deviation
576 Part Time	499 Male	20	8
107 Full Time	184 Female		

Results & Discussion

For the research questions addressing differences in GPA between courses, between male and female instructors, and between full and part time instructors, no significant difference was found between any of these variables and the overall GPA of the class. See Table 2 for test statistic values. Of particular note, this finding indicates that grade inflation is not occurring with part time instructors compared to full time instructors, at least for the courses evaluated.

For the research questions addressing end-of-course evaluation scores, again, no difference was found between male and female instructors or between full-time and part-time instructors with one exception (see Table 2 for test statistic values). For the end-of-course question, "The instructor provided meaningful and timely feedback on my assignments and progress," no significant difference was found between full-time and part-time instructors at the 95% level, however, the .0617 p-value is within 1.2% of the accepted $p = .05$ level. This finding suggests that response to this end-of-course question does exhibit some difference between full-time and part-time instructors. Overall, the mean score for full-time instructors was found to be 4.299 whereas the mean score for part-time instructors was 4.440.

Table 2
Man-Whitney Test Results

Research Question	**Test Statistic**	***p* Value**	**Results**
GPA differences between courses	18.78	.2055	No significant difference was found in course GPA
GPA differences between male and female instructors	.3322	.7937	No significant difference was found in course GPA between male and female instructors
GPA differences between full-time and part-time instructors	.6715	.5019	No significant difference was found in course GPA between full-time and part-time instructors
End of course evaluation score differences between male and female instructors (“The instructor exhibited expertise in the course subject matter.”)	-.0791	.9370	No significant difference was found in course evaluation scores between male and female instructors
End of course evaluation score differences between male and female instructors (“My overall impression of the instructor is positive”)	.0158	.9874	No significant difference was found in course evaluation scores between male and female instructors
End of course evaluation score differences between male and female instructors (“The instructor provided meaningful and timely feedback on my assignments and progress.”)	.9333	.3506	No significant difference was found in course evaluation scores between male and female instructors
End of course evaluation score differences between full-time and part-time instructors (“The instructor exhibited expertise in the course subject matter.”)	-1.051	.2933	No significant difference was found in course evaluation scores between full-time and part-time instructors
End of course evaluation score differences between full-time and part-time instructors (“My overall impression of the instructor is positive.”)	-.8466	.3972	No significant difference was found in course evaluation scores between full-time and part-time instructors
End of course evaluation score differences between full-time and part-time instructors (“The instructor provided meaningful and timely feedback on my assignments and progress.”)	-1.8685	.0617	No significant difference was found in course evaluation scores between full-time and part-time instructors at the 95% level, however, the .0617 p value is within 1.2% of the accepted p=.05 level. This finding suggests that response to this end-of-course question does exhibit some difference between full-time and part-time instructors.
Differences in response rates related to faculty gender	.9125	.3615	No significant difference found in course response rates based upon faculty gender.
Differences in response rates related to instructor employment status (full-time or adjunct	-3.228	<.01	There is a significant difference found in course response rates based upon faculty employment status.

Difference in end-of-course response scores were further evaluated to determine whether there was any significant difference in course response scores between courses identified as technical/scientific versus those classified a non-technical/arts and social science. While previous research has indicated that gender bias may be more prevalent in scientific and technical areas of study (Fan et al., 2019), this bias was not found to be the case with the evaluations studied at this university.

Response rates were also evaluated. There was no significant difference found in course response rates based upon faculty gender or between courses (Kruskal-Wallis, 25.068, $p = .296$), but there was significant difference found in course response rates based upon faculty employment status. Response rates for part-time instructors was higher than for full-time instructors, but that may be a function of sample size, with 575 part-time instructors analyzed compared to only 107 full-time instructors.

To evaluate whether there is a difference in course evaluation scores between courses, a Kruskal-Wallis test was performed since there were more than two variables. Using this test, a test statistic of 101.57 with a *p*-value <.01 was found. Therefore, a significant difference in evaluation scores was found between courses. Some courses had an overall mean evaluation score of as low as 2.60, whereas the highest mean score for one particular course was 3.58. This may support the hypothesis that student evaluations differ depending on the course (i.e., if a course is poorly designed or particularly difficult, that may result in overall lower evaluation scores, regardless of the instructor presenting the course). Looking at the mean scores by course may be a valuable tool for administration to identify courses that may need attention, and may also be useful in explaining why individual instructors may receive low evaluations when teaching certain courses.

When evaluating whether a relationship exists between course GPA outcomes and student evaluation response scores, a correlation analysis was performed. A positive yet relatively weak correlation was found for evaluation questions “The instructor provided meaningful and timely feedback on my assignments and progress” and “The instructor exhibited expertise in the course subject matter” (both $r = .22$, $p < .01$). However, there is a stronger association ($r = .27$, $p < .01$) for the question “My overall impression of the instructor is positive.” It was observed in this analysis that positive impressions increase with higher grades.

Limitations

One important impact on data integrity is the impact of nonresponse rates, which can increase the potential for error and weaken the quality of data and their results (Groves et al., 2004; Groves & Couper 1998). In the age of data-driven decision-making, it is imperative to collect and use responses representative of the whole population, but many universities fail in obtaining high response rates, particularly those from online evaluation processes (Adams & Umbach, 2012). Adams and Umbach (2012) report that in most cases, survey nonreseponse rates are not random. Bacon, Johnson, and Stewart (2016) confirmed that when response rates are low, high-scoring teachers are rated much more favorably, and low-scoring teachers are rated much less favorably, most likely because those students that do respond have a strong opinion, but the would-be scores from those who did not respond were not present to balance out the overall score. As nonresponse rates increase, the likelihood increases that the opinions of those who did not complete the survey differ from those who did, thus the data in these student surveys are not always representative of the whole population (Adams & Umbach, 2012). Multiple studies report that response rates for online student evaluations can initially average near 60%, but often drop off to the 30 to 40 percentile range (Avery, Bryant, Mathios, Kang, & Bell, 2006; Nulty, 2008; Sax, Gilmartin, & Bryant, 2003). Chapman and Joines (2017) have recommended minimum response rates for class sizes over ten, under liberal conditions (10% sampling error, 80% confidence level), a minimum response rate of 70% is recommended (Chapman & Joines, 2017). While some of the online classes evaluated for this university could have class sizes of under 10, the overall mean response rate for the courses evaluated for this study was 77%.

It is recognized that the larger the number of statistical tests performed, the greater the risk of Type I errors, or false positive results (Andrade, 2019; Armstrong, 2014). Methods such as the Bonferroni or Hochberg corrections are available (Andrade, 2019; Armstrong, 2014), but were not used in these evaluations. The study results produced very few positives thereby reducing the need for tests of false positives.

Conclusions & Recommendations

While the historic literature and personal anecdotal experiences of individual instructors may indicate that gender bias can occur, the analysis of over 683 data points does not indicate that gender bias is occurring in courses taught online or hybrid environment at this university for the time period studied. To recap the study parameters, a total of 683 sections associated with 24 courses taught in the online campus were selected for the period of March 2018 to January 2019. The courses were chosen to fit multiple parameters such as frequently taught by multiple instructors, had not been updated or changed during the study period, and were from a range of technical and general courses, including math, economics, aviation, English, research, and occupational safety topics. The data utilized was gleaned from the course section student end-of-course survey responses and GPA differences as detailed in Table 2. What should be an obvious point is that a lot of data was compiled and analyzed for this study. Through meticulous examination of the data, the authors concluded that no evidence of gender bias was evident in the end of course survey responses or differences in GPAs. Conclusions allow us to be introspective and draw inferences from the results. The conclusions were unexpected, and the results are certainly contrary to the majority of previous studies conducted on traditional classroom environments. However, the results corroborate the earlier theorization of Cohen and Ellis (2008) that ALN offer the potential to create a gender neutral communication environment and we conclude from this study that online and hybrid modalities muted gender bias in the data examined.

Beyond the lack of gender bias detected in the data, one relationship that should be pointed out is the relationship between course GPA outcomes and student evaluation response scores. The weak yet positive correlation found in evaluation questions “The instructor provided meaningful and timely feedback on my assignments and progress” and “The instructor exhibited expertise in the course subject matter” was not a surprise to the authors. When considered with the weak but stronger association for the question “My overall impression of the instructor is positive” the inference can be drawn that a student will report a positive impression of an instructor when a higher GPA in the course is achieved. Again, while not unexpected and a belief often articulated by instructors, the conclusion is troubling from a perspective that the student may perceive the instructor is the basis for the high grade rather than the grade was earned through the student’s efforts in the course. This particular issue is perhaps a conundrum that has existed as long as instructors have scored student submissions and awarded final course grades.

While the research questions evaluating bias for this study were not supported by the evidence, that fact is perhaps the most encouraging and enlightening aspect of the research. As a community of higher education institutions, we are embracing online teaching technology at an ever increasing rate with new institutions entering the market daily. The Education Department's National Center for Education Statistics reported that in 2017 of all students in postsecondary courses students in mixed online and in person courses accounted for 17.6% of enrollments and students exclusively in online courses stood at 15.4% of all enrollments (Lederman, 2018). As the demand for online and hybrid learning grows, as has occurred exponentially in 2020 as a result of the COVID-19 pandemic, so do the opportunities to make the learning environment truly gender neutral. We all strive for an environment where both faculty and students are accepted and valued and not viewed through a gender bias lens.

This research establishes an important foundation for other studies in the evolving online education environment. Online learning is persistent and the numbers support the acceptance of the modality by students even in the advent of declining postsecondary enrollments (Lederman, 2018). The authors suggest future studies be undertaken that examine student gender bias in the online environment. Does gender neutrality extend to the actual students in an online or hybrid learning environment course? Other research threads should be considered that delve deeper into the association of student course GPA to positive impressions of the instructor. The weak yet positive correlations discovered in this study indicate a more in depth inquiry into a student's perceptions of earned versus awarded grades is warranted. Additionally, the student evaluation process should be vetted further to determine whether it is a useful or outdated tool particularly for online learning environments. Should teaching effectiveness be evaluated by the data and not the student as in an online learning environment? A plethora of data resides in each course to evaluate not only faculty teaching effectiveness, but other factors that influence student evaluations today such as time in course to GPA, timeliness of grading and assignment learning outcome alignment to name a few aspects.

As noted earlier, the value of this research lies in what was absent in the data and not what was present. Bias of any type marginalizes individuals and in a learning environment it can be toxic to effectiveness of the faculty member. Moving forward, let's continue to foster this gender neutrality in online environments and take additional measures to ensure students are judged impartially as well.

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The Impact of Motivation on Continued VFR into IMC: Another Perspective to an On-Going Problem

Sabrina Woods
Embry-Riddle Aeronautical University

Steven Hampton
Embry-Riddle Aeronautical University

Scott R. Winter
Embry-Riddle Aeronautical University

Paul Craig
Middle Tennessee State University

Stephen Rice
Embry-Riddle Aeronautical University

Continued flight under visual flight rules into instrument meteorological conditions remains the predominant cause for fatal accidents by percentage for general aviation aircraft operations. There are gaps in the research in determining how motivation might influence the decision-making process. Therefore, the purpose of this study was to determine how motivation and meteorological conditions might affect a pilot's willingness to persist in flight into meteorological conditions. Four hundred and fifty-four general aviation pilots participated in a mixed factorial experiment to assess their willingness to persist in varying weather conditions. Participants were randomly assigned into one of three motivation groups (intrinsic, extrinsic, or no motivation) and were subjected to all three meteorological conditions (visual, marginal, and instrument) that were randomized in order of appearance. They were then asked to indicate their willingness to persist in each condition via a slider scale, scaled from 0 to 100. The results indicated the main effect of meteorological condition has a significant effect on willingness to persist, while the main effect of motivation did not. The interaction between meteorological condition and motivation resulted in a significant effect, particularly in the marginal meteorological condition.

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It was just after sunrise and the fog was still hanging over the airport. The private, instrument-rated pilot needed to complete a short flight across town for an important breakfast meeting. Joining the pilot on the flight was a business partner and the business partner's son. Expecting the fog to 'burn off' as forecasted, the pilot did not leave enough time to drive across town should they be unable to make this flight. Knowing an instrument flight plan would also add a severe delay due to air traffic control issues, the pilot chose to depart the field requesting a special VFR clearance, which required only one mile of visibility and remaining clear of clouds. The departure went smoothly, and the pilot was halfway across town before the fog began to thicken. Feeling committed at this point, the pilot began a zig-zag flight path to maintain visual references, when suddenly the aircraft was engulfed in clouds. Having lost visual reference, the pilot was unexpectedly forced to switch to using flight instruments to navigate and maintain aircraft control. However, the instruments were giving what felt like contradictory information. Were they climbing or descending? Turning left or turning right? As the wind began rushing by the outside of the aircraft, the pilot knew something was wrong, but it was not until the aircraft exited the clouds in a spiral dive toward to ground that the problem could be diagnosed. A last-minute effort to pull back on the control yoke proved futile as the aircraft plunged into the ground, fatally injuring all on-board.

Unfortunately, the fictitious scenario described above is not a unique one to those familiar with aviation. Many questions continue to plague aviation researchers, especially as it relates to why pilots persist in continuing flights into deteriorating weather conditions — a phenomenon that will be explored in this initial examination of what may be the influence of motivation on that willingness to persist. In 2017, the 26th Joseph T. Nall Report, a biennial review sponsored by the Aircraft Owners and Pilots Association (AOPA), examined the occurrences and suspected causal factors of GA mishaps based on 2014 data. The findings indicated that out of 1,163 GA accidents, 32 (3%) were attributed to weather-related causes (Kenny, Knill, Sable, & Smith, 2017). Of the weather category, 22 (69%) were VFR into IMC; and of those, 20 (91%) resulted in one or more fatalities. The 2014 VFR into IMC mishap fatality rate for the weather category is consistent to the previous years, which were recorded as 73% in 2013 (Perry, Kenny, Knill, Pangborn, & Sable, 2016), 95% in 2012 (Landsberg, Lenny, Smith, Pochettino, & Knill, 2015), and 93% in 2011 (Landsberg, Lenny, Smith, Pochettino, & Knill, 2014). Although weather-related issues have a relatively low occurrence, it also has a much higher fatality rate and has remained stubbornly fixed for over three decades. This is despite the development of weather forecasting technologies, the introduction of Automatic Dependent Surveillance-Broadcast (ADS-B), better training, and the presence of safety awareness campaigns.

In the past, aviation research has focused on the hazardous attitudes (*macho, impulsivity, resignation, invulnerability,* and *anti-authority*) that can disrupt the decision-making process and interfere with sound risk management (FAA, 2009). While these five hazardous attitudes were considered when developing the nature of the study, the focus of this research is on how motivation might impact the decision-making process. Motivations are the reasons why individuals behave, and therefore make decisions the way they do, while attitudes are more about a person's state of mind while making that decision.

Human factors and aviation safety researchers such as O'Hare and Owen (1999), Wilson and Sloan (2003), and Goh and Wiegmann (2001a) identified motivation as a key part of the aeronautical decision-making process, but their studies have not gone so far as to apply the behavioral subcomponents of motivation that other domains have had great success in developing. For this research, motivation is the reason or reasons a person might chose to act or behave in a certain way, or the general desire or willingness to do something. Motivation theory has been applied extensively in education, goal achievement, and job satisfaction, with the intent to quantify how human behavior and desires might translate into action and decision making. For a review of motivation in education and in job-satisfaction, it is recommended readers review Vansteenkiste, Lens, and Deci (2006), Herzberg (1966), and Herzberg, Mausner, and Snyderman (1967), respectively.

Foundational motivation theorists such as Maslow (1943, 1970), Reiss (2004), Herzberg (1966), Herzberg et. al. (1967), and McClelland (1988) have demonstrated that the manner by which a person is motivated has a direct effect on his or her decision-making process. The purpose of this study is to determine how motivation and meteorological conditions might affect a pilot's willingness to persist in flight into IMC. The following literature considered the severity of the issue in terms of occurrence and lethality, the prevailing theories that have and have not been addressed, what effect cognitive biases have on the decision-making process, and the theoretical foundations of motivation.

General Aviation Accident and Incident Archival Data Studies

According to the Federal Aviation Administration and the Code of Federal Regulations (2014), visual flight rules (VFR) are a set of regulations by which a pilot operates an aircraft in visual meteorological conditions (VMC), meaning a ceiling that is greater than 3,000 feet AGL and visibility is greater than 5 miles. Conversely, instrument flight rules (IFR) are the operating regulations pertinent to flying in instrument meteorological conditions (IMC), meaning those conditions that consist of a ceiling of less than 1,000 feet and a visibility of less than three miles. Marginal VMC (MVMC) is when the ceiling is between 1,000 and 3,000 feet and/or three to five miles of visibility.

VFR into IMC is when a pilot, who by rating or aircraft limitations, is obligated to fly by visual references only, and either chooses or inadvertently flies into weather conditions that require the use of instruments as a primary reference due to the lack of reliable out-of-window cues for orientation. Research teams have sought to determine why a pilot might persist into adverse weather conditions, particularly when he or she is flying under visual flight rules. Existing studies almost exclusively focus on risk assessment (O'Hare & Owen, 1999), skills self-assessment (Goh & Wiegmann, 2001a, 2001b), and the decision-making process (Goh & Wiegmann, 2001a, 2001b; Wilson & Sloan, 2003). For this research, *willingness to persist* is defined as the firm or obstinate continuance of action in spite of difficulty or opposition.

Goh and Wiegmann (2001a) reviewed accident data, specifically depicting VFR into IMC, and determined that *social pressure* was one of the prevailing theories as to why pilots persist. Social pressure might influence a pilot to persist, particularly when there are expectant passengers on board, or if the desire to perform in adverse conditions is present (Goh & Wiegmann, 2001a). Under this construct, social pressure most closely resembles motivation elements because the desire to please [extrinsic motivation] and the desire to perform [intrinsic motivation] become the basis for the decision to persist.

Wilson and Sloan (2003) used the NTSB and Transport Safety Board of Canada archival data from 1983 to 1999 to offer a comprehensive look at the common aspects of VFR into IMC mishaps. They noted that the pilots of the mishaps tended to be individuals who flew for personal reasons rather than commercial; and, just over 60% were flying their own aircraft. In addition to inclement weather, additional environmental factors [such as nighttime conditions, or topographical elements such as mountainous terrain] were also considered, as those elements greatly increased the lethality of the events (Wilson & Sloan, 2003). After they reviewed all of the events, the researchers asserted that pilot decision-making processes were not always rooted in rationality. Rather, most pilots were subject to bias and unrealistic optimism in their aeronautical decision making (Wilson & Sloan, 2003). An important distinction to note here is that while the Goh and Wiegmann (2001a) study attempted to assess the fundamental reasons why a person might persist in VFR flight into IMC, the Wilson and Sloan (2003) study focused on the reasons why the act would be considered a hazard.

Factors that Affect VFR into IMC

In a slight contrast to Wilson and Sloan's (2003) reasoning, Higgins (2000) argued that while all human beings are motivated to make good decisions, remaining objective is not a simple matter. There are psychological influences that take into account--not just the perceived gains and losses--but also social, moral, and emotional considerations. These additional considerations are subject to their limitations. Cognitive biases such as sunk cost, plan continuation error, and confirmation bias manipulates the resulting decision from being one that is purely objective (Goh & Wiegmann, 2001b; Muthard & Wickens, 2003; O'Hare & Owen, 1999). In the Goh and Wiegmann (2001b) study, 32 non-instrument rated participants had to fly a simulated Cessna 172 from one point to another. Unbeknownst to the participants, the flight scenario was programmed for rapidly deteriorating weather. Of the 32 participants, 22 continued with their flight. While not the focus of the study, the outcome highlighted how both cognitive bias and motivation could interact with the decision-making process.

In a similar experimental design, O'Hare and Owen (1999) subjected 20 VFR pilot participants to a scenario in which the undesirable condition marginal VFR was introduced either within the first 15 minutes of flight or the latter 15 minutes before reaching the intended destination. Participants were to fly the established flight plan and were immediately assessed once they either discontinued the flight or once marginal VFR was exceeded (O'Hare & Owen, 1999). The data showed that the timing of the introduction of inclement weather seemed to affect pilot situation awareness. The participant pilots seemed to fly longer because the perceived risk of diverting the aircraft was higher than the risk of proceeding. Confirmation bias can manifest as a pilot only seeks the data that validates his or her goal and disregards any information that runs contrary. Once vital cues and pertinent information are missed, the pilot fails to revise the plan and persists with the faulty course of action (Dehais, Causse, Vachon, & Tremblay, 2011).

In the O'Hare and Owen (1999) study, the pilots who persisted VFR into IMC exhibited very little indication that they would even consider an alternative option. The researchers postulated that this persistence, or willingness to continue, was attributed to the pilot's decision to proceed having been made far before the onset of inclement weather occurring. The willingness also indicated something else might more heavily influence the decision-making process. It is possible that whatever motivated the person to take the flight, to begin with, may have significant bearing on whether that person is willing to persist (O'Hare & Owen, 1999). In this state, the pilot is even more susceptible to bias in aeronautical decision making.

Theoretical Foundation of Motivation

Theorists such as Maslow (1943, 1954, 1970), McClelland (1998), Herzberg (1996), Reiss (2004), and Deci and Ryan (2008, 2014) have sought to better understand human behavior by conducting phenomenological studies on the attitudes, beliefs, ethics, and motivations of different groups of people. While there are a few points on which they disagree, what remains constant throughout the studies is that motivation plays a powerful role in how people conduct themselves and make decisions.

Maslow (1943, 1954, 1970) asserted that human behavior was derived from individuals seeking different levels of fulfillment. His theory of needs — from physiological to self-actualization — stands as one of the most commonly-recognized for understanding human motivation. Since Maslow, several researchers have attempted to identify further and isolate the behaviors, ideas, and characteristics that seem to affect why a person pursues an interest. Reiss (2004) argued that motives are the reasons by which a person will perform voluntary behavior. McClelland (1988) believed that people would exhibit different characteristics based on whichever motivator was more dominant and argued that the actual motivations were the result of learned behaviors rather than something inherent to the person. Lastly, Herzberg's (1966) two-factor theory determined that though job satisfaction is influenced by both forms of motivation, intrinsic motivators such as a sense of achievement and belief in the work might affect one's willingness to persist more than extrinsic elements such as pay or benefits.

The two sub-components of motivation are defined as being extrinsic or intrinsic. *Extrinsic motivation*, or external pressure, refers to when a person is driven to act by external influences such as financial reward, accolades, or the desire to avoid punishment (Deci, Ryan, & Koestner, 1999; Deci & Ryan, 2014). Extrinsic motivation can factor heavily in the pilot's decision to persist with a flight and therefore warranted additional research. Internal or *intrinsic motivation* arguably has an even more profound and yet almost imperceptible effect on the decision-maker. For the purpose of this study, intrinsic motivation is when the act or behavior is driven by internal or personal reward (Deci & Ryan, 2000).

Current Study

A willingness to persist refers to a willingness to continue in pursuit of a goal despite the contrary information indicating that doing so is no longer the optimum choice. Understanding how different motivations might affect ones' willingness to persist will help to refocus and build new platforms for pilot education, training, outreach, and prevention with the ultimate goal of decreasing the number of weather-related accidents and the associated fatality rate .

The purpose of the study was to determine how different motivations and types of meteorological conditions affect a pilot's willingness to persist flying into meteorological conditions. The literature did not support directional hypotheses, and therefore non-directional ones were proposed. The research sought to test the following hypotheses:

H_1 – There is a significant difference in indicated willingness to persist in VFR flight into IMC based on the type of motivation.
H_2 – There is a significant difference in indicated willingness to persist in VFR flight into IMC based on the type of meteorological conditions.
H_3 – There is a significant interaction between type of motivation and type of meteorological conditions on pilots' indicated willingness to persist in VFR flight into IMC.

Methods

Design

The research followed a quantitative, mixed factorial design. The between-participants factor was motivation, and the within-participants factor was meteorological condition. A two-way mixed analysis of variance was conducted to assess the main effects and interactions. All weather scenarios were presented randomly to the participants.

Participants

The target population was general aviation pilots who hold either a recreational, sport, private pilot, airline transport pilot (ATP), or commercial certificate. The accessible population was pilots who were available via electronic means of communication. The sample was sourced through the Curt Lewis' Flight Safety Information daily newsletter and the Federal Aviation Administration's *Safety Briefing Magazine*. Five hundred and twenty-nine responses were recorded resulting in 454 usable sets of results. The most common reason for case elimination was incomplete and non-qualifying data.

Of the participants, 226 (49.7%) held a private certificate, 140 (30.8%) held a commercial, 81 (17.8%) held an airline transport pilot, 6 (1.3%) held a sport, and 1 (.2%) participant held a recreational certificate. Experience level ranged from 40 hours to more than 34,000 hours, with an average of 3,443 hours (*SD* = 5,698), and median of 1,100 hours. The participants recorded ages ranging from 18 to 85 years old with a mean of 56.07 (*SD* = 14.80). The respondents were 92% male, 7% female (with 1% choosing not to answer). Sample ethnicities included: 89% white/Caucasian, 2% Latino/Hispanic, 1.5% Asian/Pacific Islander, fewer than 1% listed being Native American, 1% identified as other, and 6% chose not to answer.

Materials and Procedure

Participants were solicited through electronic recruitment, which provided a link to an online questionnaire accessed through SurveyMonkey™. Participants were presented with a consent form and instructions. The introductory scenario restricted the participant to flying a Cessna 172, equipped with a Garmin G1000 avionics suite, from an fictitious fixed-base operator for a VFR cross country flight from Colonel James Jabara Airport (AAO) just outside Wichita, Kansas, to Lancaster Regional Airport (LNC), Lancaster, Texas. Each participant was informed that they had a full tank of fuel with just over 40 gallons on board. The aircraft had a restricted certification for VFR flight only. Even if the participant was IFR qualified, the aircraft will not allow for that option.

Next, they were randomly assigned to one of three groups representing three motivation categories: *intrinsic*, *extrinsic*, and *no-motivation*. Regardless of the motivation the participant was assigned, each pilot encountered all of the meteorological conditions ─ *VMC, MVMC,* and *IMC* ─ to which each person expressed their attitudes toward their individual willingness to persist. Perceived willingness was determined by a slider scale set by percentage from 0 to 100 percent.

The three motivation scenarios are as follows:

Extrinsic – The two of you have bought nonrefundable VIP tickets to the “BIG” game and have a whole grand weekend planned out. In addition, you have won the "biggest fan" accommodations package that includes a stay at a 5-star luxury hotel. You will forfeit this if you do not show up on time.

Intrinsic – The two of you are looking forward to surprising friends and family whom you haven’t seen in years. They are unaware you are flying in just to come see them. You are excited about the big traditional holiday gathering and are eager to show off your piloting skills.

No-motivation – The two of you have been given coupons to a famous aviation museum that has been getting good reviews online and by word of mouth. The coupons are good for free entry and they do not expire. You have nothing else going on so you decided to go check it out.

The types of meteorological conditions were crafted based on federal regulation criteria. Since all participants responded to all three weather scenarios, their appearance in the survey was randomized for each person to avoid order effects.
The meteorological scenarios are as follows:

VMC – You are about 40 minutes out from your destination. A quick check of the conditions at your destination indicate visibility is 10 nautical miles with a 6,000-foot ceiling.

MVMC – You are about 40 minutes out from your destination. A quick check of the conditions at your destination indicate visibility is 3 nautical miles with an overcast cloud layer at 2,500 feet AGL.

IMC – You are about 40 minutes out from your destination. A quick check of the conditions at your destination indicate visibility is 2 nautical miles with an 800-foot overcast cloud layer.

The participants also provided demographic data, were thanked and dismissed.

Results

Descriptive Statistics

SurveyMonkey™ automatically and randomly sorted the participants into different motivation categories with the breakdown equaling *n* = 145 participants for the *extrinsic* motivation category; *n* = 167 for the *no-motivation* category; and *n* = 142 for the *intrinsic* motivation category. The scores for the dependent variable *willingness to persist* was recorded via sliding scale by percentage. The mean scores recorded by the participants, for each weather condition, and each motivational category is shown in Table 1.

Table 1
Mean Scores and Standard Deviations for Dependent Variable by Type of Weather Condition and Type of Motivation.

	Motivations	Mean	Std. Deviation	*N*
VMC	Extrinsic	95.96	13.609	145
	No Motivation	97.37	10.323	167
	Intrinsic	96.51	11.453	142
	Overall	96.65	11.794	454
MVMC	Extrinsic	59.77	32.745	145
	No Motivation	51.59	34.924	167
	Intrinsic	59.21	34.907	142
	Overall	56.59	34.376	454
IMC	Extrinsic	15.83	25.466	145
	No Motivation	10.23	22.157	167
	Intrinsic	14.32	25.817	142
	Overall	13.30	24.482	454

Note: The summary of the mean, standard deviation, and sample size (*N*) for the dependent variable: willingness to persist.

Initial Data Analysis

It was determined that the majority of the outliers were truly representative of participants' indicated willingness to persist VFR flight into IMC, because identifying and assessing this willingness is the main purpose of this research, these scores were not removed from the dataset. A Shapiro-Wilk test for normality was significant ($p < .05$) therefore, the data did not meet the assumption of normal distribution. Due to the violation and without a sufficient non-parametric test to use, the robustness of the ANOVA was considered. With large sample sizes and particularly those over 100 (in this study N = 454), deviations from normality are not considered to have an influence on the results and result in only minor deviations in the findings (Field, 2009; Oztuma, Elhan, & Tuccar, 2006). This deviation has not been shown to affect the results of a parametric test (Pallant, 2007; Oztuma et al., 2006), and, therefore, many researchers accept the use of ANOVA whatever non-normal distribution exists within the dataset as long as this limitation is clearly disclosed (Carifio & Perla, 2008; Norman, 2010).

Inferential Statistics

Results of the two-way mixed ANOVA indicated no statistically significant main effect existed for Type of Motivation (H_1) on the dependent variable [$F(1, 451) = 2.428$, $p = .089$], partial $\eta^2 = .011$. This finding means that the type of motivation alone had no statistically significant effect on participants' indicated willingness to persist.

A statistically significant main effect ($p < .05$), with a large effect size, existed for the Type of Meteorological Condition (H_2) on the dependent variable, [$F(1.874, 845.195) = 1704.242$, $p < .001$], partial $\eta^2 = .791$. This finding means that the weather conditions alone had a statistically significant effect on the participants' indicated willingness to persist.

The main effects were qualified by a statistically significant interaction ($p < .05$), with a small effect size, between Type of Motivational and Type of Meteorological Condition (H_3) on the dependent variable, [$F(3.748, 845.195) = 2.524$, $p = .043$], partial $\eta^2 = .011$.

Three separate tests for simple main effects were accomplished on the data to determine which might be significant. The test for between-participants effects on willingness to persist in VMC or IMC indicated there were no statistically significant differences: $p = .542$ and $p = .111$, respectively. There was a significant difference in willingness to persist in the MVMC condition, [$F(2, 465) = 3.193$, $p = .042$], partial $\eta^2 = .014$. Two post hoc tests were then completed to determine which means were significantly different from each other within the MVMC category (Table 3). Figure 1 depicts the main effects and interaction.

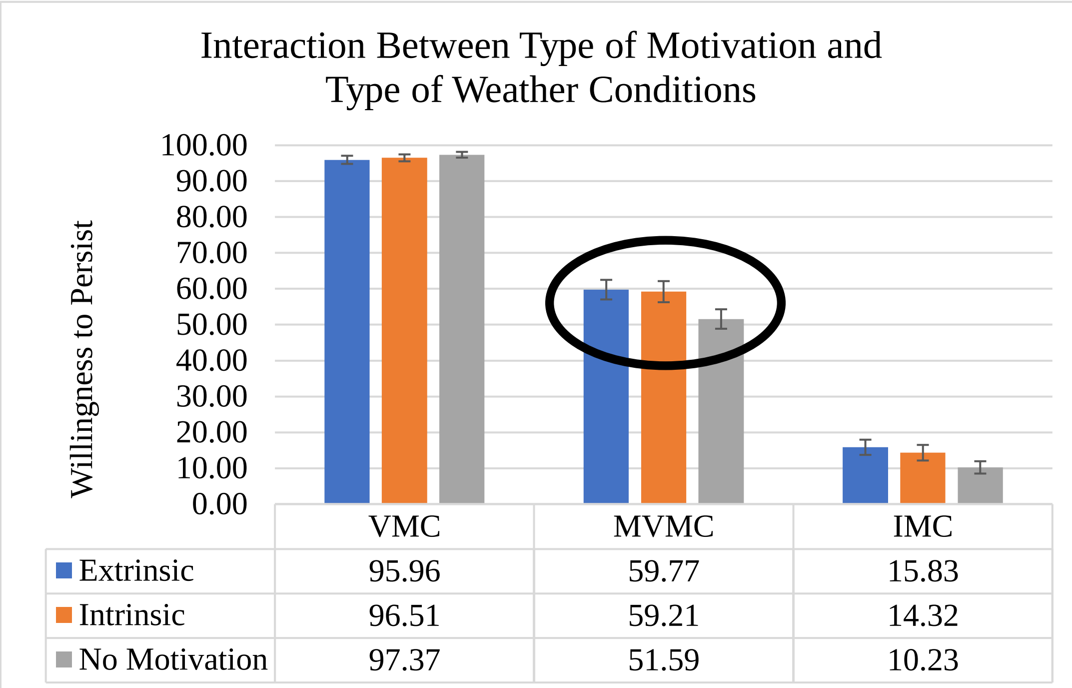

Figure 1. Pilot willingness to persist scores based on weather conditions and the type of motivation. The graph highlights the significantly greater willingness to persist of extrinsic and intrinsic motivation compared to no motivation within the MVMC category. The significant interaction is circled and visually depicted by the significant difference between the no motivation condition and the extrinsic and intrinsic conditions. Standard error bars depicted.

Using the Least Significant Difference (LSD) post hoc test, the extrinsic and intrinsic motivation categories indicated a statistically significant difference in mean scores (p = .032 and p = .030, respectively) from the no-motivation category in indicated willingness to persist. Both the extrinsic and intrinsic categories indicated a higher willingness to persist than the no-motivation category. They did not, however, indicate a significant difference from one another.

Discussion

The purpose of this study was to conduct a quantitative factorial design on general aviation pilots to determine how different motivations and different types of meteorological conditions might affect one’s willingness to persist in flight. The data indicate that motivation by itself did not have a significant effect on the willingness to persist. This question was posed because, while motivation is often mentioned by researchers as having a profound effect on the decision-making process, the theoretical components of motivation have not been specifically mentioned or applied to this domain. Herzberg’s (1966) and Herzberg et. al. (1967) two-factor theory was one of the first to identify the two different fundamental components of motivation — intrinsic and extrinsic — and their relative effect on the decision-making process. It suggests that though people are influenced by both forms of motivation, intrinsic motivators affect one’s willingness to persist more so than extrinsic elements (Herzberg, 1966). Although this theory was ultimately not corroborated within this research, there was some expectation that the trend of intrinsic motivation having more influence might reflect in the effect of motivation on the dependent variable.

The results also indicated that the meteorological condition had a significant effect on willingness to persist. Higgins (2000) postulated that all human beings are motivated to make good decisions and that an objective-based decision is one where the outcome achieves the highest benefit while requiring the lowest costs. Therefore, it made sense and was expected that the participants' willingness to persist in-flight decreased as meteorological conditions decreased. There were, however, significant outliers that indicated some participants' willingness did not decrease as conditions decreased at all; or it did not decrease at the same rate as the majority of participants. While outliers are often seen as anomalies that must be dealt with in experimental designs, these outliers represent attitudinal data that indicates some participants are willing to persist into inclement weather despite not being equipped to do so and therefore reinforce the need for this research. The findings from these main effects were qualified by a significant interaction between meteorological conditions and motivation, although with a small effect size. Specifically, intrinsic and extrinsic applications seemed to reflect a difference from the no-motivation application. The former categories reflected a higher willingness to persist over no motivation, within the marginal VMC weather condition. This finding implies that *some* motivation might affect willingness to persist over no motivation at all.

A consideration of what motivation and goal-achievement behavior entails, combined with an understanding of the inherent cost-benefit analysis all individuals partake in when confronted with a decision, helps to explain why this interaction might have occurred. First, a person is more likely to persist when he or she has a goal to achieve. Second, the requirement to make such a decision is only necessary at the onset of any obstacle that runs contrary to that initial task.

On some level, motivation can factor into willingness to persist, particularly when the ability to make an accurate assessment of the weather condition becomes challenged as it is in MVMC. Studies have shown that deteriorating weather identification is not as simple as recognizing the FAA standard, appreciating the danger, and reacting to it. In the Goh and Wiegmann's (2001a) study, their concept of *situation assessment* postulated a pilot likely persists into flight simply because they are unaware that they are doing so at the time. This concept considers a pilot's ability to correctly diagnose the weather and presumes that were a pilot to accurately assess the situation for the hazard it is, they wouldn't persist (Goh & Wiegmann, 2001a).

Further research into weather dissemination tactics from the FAA's William J. Hughes Technical Center confirms that a pilot's actual ability to correctly diagnose the weather can be quite limited (Ahlstrom & Jaggard, 2010; Ahlstrom & Suss, 2015). These limitations would be the same for the effect of the interaction between motivational category and meteorological condition on the dependent variable. Compounded with a motivationally-backed desire to continue and the result is an unintentionally skewed pilot risk assessment process and leave him or her more susceptible to bias. The result is negatively affected aeronautical decision making and situation awareness. To what level motivation can be a factor on decision making, still has to be defined.

Practical Applications

GA advocates such as the FAA Safety Team, the Aircraft Owners and Pilots Association, and the Experimental Aircraft Association have already contributed significant resources and research on the subject of proceeding VFR into IMC. Each of these organizations, as well as many others have produced seminars, courses, online content, and case studies to educate the flying community. Currently, much of the focus on mitigating the VFR into IMC phenomenon has been on developing new weather forecasting and dissemination technologies. This has been done with the belief that a pilot who is supplied with tools necessary to better predict meteorological conditions would then avoid inclement weather. While the reasoning is well-founded, the fixed accident rates do not support the theory that better weather applications help decrease VFR into IMC mishaps. The current study suggests that the decision to continue is affected by more than just the available forecast at the time.

Humans have a limited amount of mental energy to devote to making choices. In the highly-dynamic environment of piloting an aircraft, that mental energy is likely to deteriorate even quicker, while the need to respond very quickly is likely to be quite high. When confounders such as motivation and desire are introduced, the ability to select the decision that renders the most desirable outcome can become challenged. Motivation directs a person's behavior towards specific goals, determines how much he or she is willing to persist and therefore affects the choices he or she makes. For pilots to make better decisions, they have to be educated about their limitations, and fully informed about the contributing factors affecting that decision. The argument is that a knowledgeable pilot will be more encouraged to develop different courses of action that he or she can then activate depending on the situation. The absence of the proverbial *plan B* can often encourage an individual to continue in a known course of action rather than risking the relative unknown result of a deviation. In addition, a pilot who is mindful of his or her own limitations is more likely to set and adhere to personal minimums, such as the avoidance of inclement weather. The ultimate goal is to decrease the number of weather-related accidents and, therefore the associated fatality rate.

Limitations

While the results of the study were interesting, the data was limited in its ability to present a clear picture of how motivation and the interaction of motivation and meteorological conditions affects aeronautical decision making and the willingness to persist. There was some expectation that the motivations alone would interact with the dependent variable differently, following the trends already established by research in education performance and job satisfaction. The fact that motivation has not affected the dependent variable in the same manner under this specific experimental construct does not preclude the idea that a differently designed experiment might produce divergent results.

As for the interaction between motivation and meteorological condition on the dependent variable, the initial results warrant further investigation. Additional research would help refine some of the ambiguity so that a clearer depiction of which variables have a significant interaction could come to fruition.

Lastly, a fundamental limitation of this type of experimental research is that it represents an artificial situation that does not always depict real-life situations. For future research, the study could be repeated in a direct observation experimental design in either a full or partial motion simulator to see if any of the results are replicated. An observational study of this type would result in higher-fidelity scenarios and situation circumstances for the participants. The participants would still be randomly sorted into the motivational categories; however, the weather scenarios would become a visual depiction within the simulator. Observing the participants' reaction to encountering different meteorological conditions would provide a more direct method of interpreting deteriorating conditions and would mitigate the risk of the participants recognizing the weather condition as it is written. Instead of indicated willingness to persist annotated as a percentage on a slider scale, the time the participant continued in simulated flight would be recorded on a ratio scale.

Conclusions

Using a quantitative factorial experimental design, the study gathered data to support the idea that motivation may affect a general aviation pilot's willingness to persist in VFR flight into IMC. Of the three research questions and associated hypotheses the most interesting result indicated that the interaction between both meteorological conditions and motivation might have a significant effect on willingness to persist in marginal visual meteorological conditions. The potential for some motivation, versus no motivation, to effect willingness to persist aligns with Higgins (2000) research on objective-based decision making. It also supports what researchers have determined about plan continuation error and the biases that interfere with a pilot's decision-making process and risk analysis. The motivation to proceed manifests as confirmation bias and continuation error and limitations in the pilot's decision-making capacity manifest into bias (Goh & Wiegmann, 2001b; Walmsley & Gilbey, 2016). The result is a desire to continue and the unwillingness to revise the plan despite a rapidly mounting hazardous situation. Understanding how different motivations might affect ones' willingness to persist will help to refocus and build new platforms for pilot education, training, outreach, and prevention with the ultimate goal of decreasing the number of weather-related accidents and the fatality rate associated with them.

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Women in Aviation: A Phenomenological Study Exploring the Needs and Wants Necessary for Graduation

Eugene Kim
Embry-Riddle Aeronautical University

Jorge L. D. Albelo
Embry-Riddle Aeronautical University

Despite the increased awareness of gender and race equality movements, today's population of minority women in aviation is still underrepresented. This research focused on underrepresented minority women who want to pursue a career in the aviation field and what factors affect their level of success in a specialized aviation higher education institution. There is not enough data and research surrounding the topic of minority women in aviation and their paths to success in these institutions. This qualitative research aimed to bridge the existing gap in the literature related to minority women in aviation and their needs and wants to complete a four-year degree. The research objective was to raise awareness for equality of race and gender in aviation higher education institutions and explore the needs and wants that could lead to academic success for minority women. The qualitative research design brought in six students who identify as a minority woman defined by conditions set upon by the researchers, and they were asked a list of questions in a semi-structured interview format. The qualitative data collected from in-depth interviews helped identify significant aspects and patterns that minority women in aviation recognize as needs and wants that could lead to academic success. Open communication, friendship and community, and positive faculty support were identified as the perceived needs and wants of minority female students in aviation. These findings can be used to better serve underrepresented students in an aviation specialized higher education institution. In conclusion, the findings can be used to bring awareness on an issue that is not widely studied or discussed in educational aviation institutions.

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Numerous studies have explored race and gender inequality issues in four-year degree institutions and factors that affect student attrition rates. However, there is scant literature on underrepresented female minorities in aviation-specific institutions that confer a four-year degree for aspiring pilots. This study was framed using Derrick Bell's (1973; 1995) critical race theory (CRT) and John Bean's (1980) theory of student attrition. The present study focused on minority female students who were enrolled in an aviation four-year degree, and how they define their college career needs and wants to achieve success. At this stage in the research, *underrepresented minorities* are defined as individuals who do not identify as Caucasian. Furthermore, in an effort to increase research inclusion and minimize discrimination among the sample population, both *cisgender* and *transgender* women were part of this study. The term cisgender refers to those individuals whose sense of personal identity correspond with their birth sex, and the term transgender refers to an individual's whose sense of identity does not correspond with their birth sex. This study proposes further research to be conducted in order to address the issue of gender and race inequality that still exists in modern higher education institutions and especially those with an aviation focus.

Background

The term minority refers to the implication that there is a significant lack of numbers within a grouping of people (Pawley, 2019). The word minority could also be interpreted as the lack of power of a group that experiences some level of discrimination, which is more applicable to this study. According to Omi and Howard (1994), minority groups experience unequal treatment which impact a significant aspect of their lives. Inequality can be observed through a historical perspective, with predominant examples being slavery and segregation. The contemporary human rights movement is paired with the civil rights movement, both focusing efforts into combating any form of oppression and discrimination (Anti-Defamation League n.d.; United Nations n.d.). In these events, discrimination was present based on race and ethnicity. Although both slavery and segregation have been abolished, unequal representation of minority groups and bias towards minority members is, to this day, present in our society (Pawley, 2019; Rask, 2010). More actions are being taken to combat the effects of past discrimination in job hiring practices and college application acceptance. Affirmative action refers to deliberately choosing to hire or select candidates of individual races who have previously been discriminated against (Gaskill, n.d.). For example, it is commonly seen in applications where the applicants are asked to report their race and ethnicity.

The present study enables the understanding of the needs and wants of women in aviation in several ways: as a contribution to the literature about adult females' experiences in aviation education working towards completing a four-year degree; as a qualitative phenomenological study in aviation higher education; and, as an aspect of students' professional development with regards to retaining minority females in aviation education programs.

Literature Review

This review of the literature analyzes and identifies relevant theories and gaps in the existing literature. Limited literature regarding underrepresented aviation female students in a collegiate setting has been identified as the existing gap. This literature review expands the examination of underrepresented students in the context of other science, technology, engineering, and mathematics (STEM) fields. The guiding theories of this literature review are those of Derrick Bell's (1973; 1995) critical race theory (CRT) and John Bean's (1980) theory of student attrition.

Bell's (1973; 1995) critical race theory (CRT) focuses on racially motivated injustice while removing religious and ethnic inequalities. The use of the CRT as a theoretical framework enabled the researchers to understand the essence of achievement for racial minorities and, therefore, can be applied in higher education institution (HEI) research (Crenshaw, Neil, Gary & Kendall, 1995; Gillborn, 2006). In recent years, HEIs have focused on diversifying their students and faculty to better serve the more globalized professional industries and their interest in campus diversification (Hurtado & Ruiz Alvarado, 2015; Luedtke, 1994). It is essential to be aware of this increasing trend and create a suitable setting for minority students to obtain higher education in a safe and welcoming environment (Aljohani, 2016). On the other hand, some institutions seem to only improve the face-value of the school by artificially diversifying its pool of students. However, it is shown that the rate at how the traditionally underserved students (TUS) succeed and complete their degrees should be the focal point, rather than the number of TUS who attend a particular school (Gillborn, Warmington, & Demack, 2018). The number of TUS was observed to be much higher in HEI, specifically institutions focused on STEM majors (Bancroft, 2018; Ong, Smith, & Ko, 2018).

Furthermore, minority female students in aeronautical science and flight degree programs are deeply underrepresented, even though they make up for a significant number of the student body (Meyer, Cimpian, & Leslie, 2015). Due to the lack of underrepresented female minorities' studies in aviation, some aviation-specific HEIs are unable to analyze its body of TUS and their learning environments correctly. It is challenging to critically assess how gender and race operate in the field of STEM as these education systems and class differences have already been established for decades (Pawley, 2019).

The theory of student attrition focuses on the retention rate of students enrolled in HEI and the factors that affect their decision to stay enrolled or drop out (Bean, 1980; Bean & Metzner, 1985; Spady, 1971; Tinto 1975). There has been an increasing demand and interest in developing models and theories that explain the factors affecting student dropout (Mannan, 2007). One area of interest for policymakers, researchers, and educational leaders is improving the low retention and graduation rate of STEM fields. Early withdrawal from HEI can be strongly associated with academic-related skills and how the students adapted to academic and social life. Factors such as academic preparedness, academic experiences, institutional expectations, academic and social match, family support and commitment, and university financial support services are identified as critical influencers to a student's ability to complete a degree (Webb & Cotton, 2018). In the readily evolving global labor market, studying how student attrition differs in aviation-specific HEI could become valuable not only to the university's marketing and recruiting practices, but it is also set in the right direction. If these factors can be clearly identified and labeled, HEI can increase institutional commitment to students; therefore, decreasing the level of dropout of TUS (Bean, 1980; Bean & Metzner, 1985). The student attrition theory in this study provides a theoretical foundation and structure for explaining minority female aviation students' ability to succeed in an industry dominated by males while increasing their retention rate.

Historically, female and black pilots were segregated since World War II (Vaughan, 2016). The world witnessed a great increase in demand for pilots as technology developed over the years, and more people were traveling in the air. General aviation was a small portion of the industry that allowed females to learn how to fly and enter this prestigious workforce (Bednarek & Bednarek, 2003; Ison, Herron, & Weiland, 2016). More female pilots were certified after World War II, and along with opportunities from the Air Force and the space program, the number of female pilots grew steadily (Luedtke, 2011). Amelia Earhart is undoubtedly one of the most influential figures in aviation history, but the list of important female pilots is much longer.

There is an evident connection between race and gender, and student attrition rate in HEI. Historically, females have been underrepresented in aviation, and their numbers remain on the lower end (Ison et al., 2016; McCarthy, Budd, & Ison, 2015). Aviation HEIs should become concerned regarding neutralizing racism on campus and increasing student retention rates (Bancroft, 2018; Ong et al., 2018; Rask, 2010). It could be argued that there is a demand for increased awareness of gender and race-related issues on aviation HEIs, which could provide a safer and more welcoming environment for students. A further continuation of research into the field of aviation-specific institutions will enhance the understanding of student attrition in STEM majors as well as for the more specific and global market of aviation. By understanding the deeply rooted impact of race and gender on student attrition rate, the presence and representation of female pilots in the aviation industry can be positively improved for the future generation.

Significance

The findings of this study are important for society, as the emphasis on diversity and the role of minority members continue to increase. Research has shown that there have been a limited number of studies that focus on minority women's experience in college readiness and the factors that affect their academic progress (Bednarek & Bednarek, 2003; Luedtke, 2011). This study focused on minority women, specifically in aviation specialized HEIs who are pursuing flight training. Thus, schools with a specialized emphasis on aviation, and other related STEM degrees, will be able to use the findings of this study in order to better serve TUS. Furthermore, the present study can be used as a tool to bridge the existing gap in the literature related to minority women in aviation, and their needs and wants to complete their four-year degree.

Problem Statement

Recent studies in the field of aviation show that there is limited data or research surrounding the topic of minority women in aviation and their paths to success in HEIs (Bancroft, 2018; Ong et al., 2018). This qualitative research aimed to bridge the existing gap in the literature related to minority women in aviation and their needs and wants to complete their four-year degree. The objective of this research was to raise awareness for equality of race and gender in aviation HEI and to explore factors that could lead to academic success for minority women in aviation.

The research question driving the study was:

- How do minority women in aviation define their needs and wants to achieve success and complete their four-year degree?

Methodology

According to Creswell & Poth (2018), qualitative research allows the researcher the opportunity to explore the data and formulate an understanding. Furthermore, qualitative research is used to "make sense of and recognize patterns among words in order to build up a meaningful picture without compromising its richness" (Leung, 2015, p. 324). Therefore, rather than striving to achieve generalizability in the findings, phenomenological qualitative research strives to add extra dimensions and perspectives to the corpus of findings through rich descriptions of the lived experiences (Creswell & Creswell, 2018; Creswell & Poth, 2018; Moustakas, 1994). This study aimed to build a depth of understanding around minority women's success in their aviation college career. The foundational structure of the research revolved around the guiding theories of CRT and the student attrition theory. A qualitative phenomenological approach was the most appropriate because it is important to understand the common and shared experiences of several individuals regarding the phenomenon in question (Creswell & Creswell, 2018). Moustakas (1994) also pointed out that phenomenology seeks meanings from appearances and arrives at essence through intuition and reflection of conscious acts of experience. The literature supports a gap in research regarding the factors that influence minority females to succeed in their aviation college careers. The primary data collection was done through semi-structured interviews. The interview questions were validated by a former female airline pilot and aviation professor whose subject matter expertise is in diversity and inclusion in aviation education. Table 1 shows the interview questions developed for this study.

Table 1
Interview Questions

1) Tell me about yourself.
   a) Born and raised
   b) Background
   c) Race identification
2) How the faculty interactions helped you persist to complete your aviation degree?
3) What are your perceptions of minority women in completing a four-year degree?
4) What factors do you think contributed to minority women being underrepresented in the aviation field?
5) What strategies or skills do you perceive were necessary to be successful in the aviation higher education system?
6) How has being a minority woman in a four-year aviation college affected your ambitions for your future?
7) What are your plans after obtaining your bachelor's degree in aviation?
8) What are your recommendations for improving the success rate of minority women completing their four-year degree in aviation?
9) What factors kept you motivated to complete your four-year aviation degree?
10) How do you define success in college?

Because Creswell and Creswell (2018) suggest a purposeful sampling for qualitative research, participants included six aviation senior undergraduate female students from an aviation HEI located in Florida who identified themselves as underrepresented minorities.

Furthermore, the objective of this research methodology was not to yield generalizable results, but to generate an understanding of the lived experiences of the participants (Creswell & Poth, 2018) and to lay a foundation knowledge for future research explorations in aviation education.

Participants

The sample for this qualitative research followed Creswell and Poth's (2018) small sampling suggestion in order to support the depth of phenomenon-oriented analysis that is fundamental to this mode of inquiry. This research focused on six self-identified cisgender or transgender females enrolled in a four-year degree program. Participants were full-time undergraduate aviation students. Furthermore, these participants were seniors and had attended at least two semesters at the research site. Participants were asked to disclose their ethnicity, which was broken down to Asian, Black, American Indian /Alaska native, Hispanic or Latino, Native Hawaiian or Pacific Islander (see Table 2).

Table 2
*Participants Demographics (*Pseudonyms)

Name	Ethnicity	Age
Diana	Asian	21
Linda	Asian	21
Lois	Hispanic	22
Marge	Hispanic	20
Peggy	Asian	21
Penelope	Asian	20

Setting

The participants of this research are students of an aviation-specific HEI located in Florida. Around 70% of this institution's student body is made up of male students, so due to the evident nature of the institution, the number of minority female students is low.

Due to the Covid-19 pandemic, interviews were scheduled and conducted online via Zoom conference calls. These video conference calls allowed the interviews to be conducted at a time that was convenient for both the researcher and the participant in their own space. The recordings of each interview remained confidential and secured for data analysis.

These interviews were scheduled in advance and were around 30-40 minutes. The primary researcher conducted the interviews through an online Zoom conference call with the supporting researcher present as a secondary line of contact in case the call experienced technological difficulties. As mentioned before, the primary researcher did experience some internet connection issues where the researcher's mic was briefly cut out, and the supporting researcher was able to fill in the missing portion to prevent confusion.

Recruitment Process

Participants were selected via purposeful sampling. The supporting researcher used an internal student demographics list to identify self-identified minority females in the aviation program of the research site. The supporting researcher compiled a list of potential candidates and sent it to the primary researcher. Eleven participants received a recruitment email from the primary researcher extending an invitation to participate in the study; only 6 replied showing interest. Each email had the consent form attached to it. They were asked to sign an online interest form for basic information and an informed consent form to agree to the conditions. This research was sponsored by the Embry-Riddle Aeronautical University (ERAU) Summer Undergraduate Research Fellows (SURF) program. Furthermore, the research was approved and reviewed by the ERAU Intuitional Review Board. Participants were informed that their names were going to be entered in a random drawing for the chance to win a one hundred dollars for their participation. When the participant showed interest by completing these two documents, a separate email was sent to schedule the time and to inform the process to conduct the interview via Zoom.

Data Analysis

The data analysis was conducted as an ongoing process. As soon as individual interviews were completed, the researchers transcribed them and sent them back to the participants for review and approval. After approval from each participant, the researcher engaged in data analysis. The data was coded manually so that the primary researcher was forced to think and deliberate, generate codes, and reject and replace them with others that were more illuminating and which seem to explain the phenomenon better (Creswell & Poth, 2018). As suggested by Moustakas (1994), the researcher engaged in an epoche process so that they were able to actively listen, observe, and interact with the data through the lived experiences of the participants. First, coding was used to identify *significant statements* that were made by the participants. Significant statements were identified and clustered into themes (Creswell & Creswell, 2018). As themes emerged and duplicated, they were reduced to construct the essence of the experience (Creswell & Poth, 2018) and were analyzed in the context of the CRT and the student attrition theory. Focus on textual descriptions of the lived experiences provided the *what* of the phenomenon. Once the phenomenon was identified through the participants' own words, they were used to answer the research question. It is important to point out that as part of the data analysis, the term *needs* was defined as the elements that students must have accessible; while *wants* was defined as self-perceptions of what needs to be accessible.

To ensure the trustworthiness of this qualitative research study, member checking procedures and external peer review were utilized. Creswell and Poth (2018) affirmed that member checking enables researchers to solicit the participants' views of the credibility of the findings. All participants had the opportunity to review the transcripts of their interview responses to ensure accuracy. Furthermore, the researchers followed Creswell and Creswell's (2018) suggestion of seeking a peer review external to the research to ensure the integrity and accuracy of the research. The external peer review member was a female aviation professor whose subject matter expertise is in diversity and inclusion in aviation education.

Findings

To answer the research question, information collected from the personal interviews was analyzed, and themes were developed from recurring codes to describe how the participants defined their college career needs and wants to achieve success in the aviation education field.

Epoche was the primary strategy used by the researchers to bracket their experience with the topic of study to fully examine the participants' perceived needs and wants. Moreover, the researchers then used phenomenological reduction in order to develop meaning from the text (Creswell & Creswell, 2018). After significant statements across participants were clustered together, three major themes emerged that answered the research question (see Table 3).

Table 3
Open Codes and Themes

Open codes	Appearances across data sets	Category
Goal Sharing	19	Open Communication
Opinions	16	
Stereotype	15	
Culture	10	
Connections	8	
Network / networking	8	
Respect	7	
Obstacles	5	
Appealing	4	
Intimidating	4	
Perspective	4	
Communication	3	
Family & friends	44	Friendship and Community
Motivation	22	
Female pilot	21	
Women in Aviation	14	
Community	13	
Representation	7	
Relationships	5	
Scholarships	4	
Professor(s)	45	Positive Faculty Support
Support	44	
Experience	36	
Knowledge	18	
Career	15	
Opportunity	12	
Interaction(s)	11	
Environment	8	
Participation	8	
Role model(s)	8	
Involvement	7	
Mentorship	6	

Theme 1: Open Communication

The most prominent theme that emerged during this study was open communication. Communicating one's ideas to professors, classmates, and family members can be challenging as it requires a specific means of communication. The participants in this study seem to agree with the fact that being able to ask questions and receive answers enables them to achieve success. Penelope best exemplified this ideal when she stated,

> I go to office hours a lot because I'm always searching for human interaction and just a lot of advice. I'm always trying to find advice in my life path because all of our professors pretty much have experiences in the industry.

Moreover, the participants' responses seem to support the fact that strong and open communication is a cornerstone of success in academia. Evidently, open-communication empowered this group of females to get to know other females and male-peers on a personal level, boosting their confidence towards achieving the completion of their degree. Diana explained that the definition of success in college could be seen as the connections she has made and the life-long relationships she has built during college. Furthermore, Linda confirmed when she commented that, "a successful college experience is looking back and reflecting on the friends that you've made, and the connections you have acquired." Students seem to value an open environment for communication and support validation.

Students seem to utilize their professors' office hours and normal class interactions in forms of meaningful discussions. The ability of faculty to provide a safe environment for students to share their concerns and thoughts determined the level of comfort of the student, which led to their greater success (Webb et al., 2018). Open communication not just among peers but with instructors and professors can lead to the student developing life-long connections with them. Lois stated, "we still keep in touch and he's just always giving advice and insights to his career, and if I ever needed help with anything, he'd always be lending a hand to help." Open communication between the students and the faculty, as well as among peers in a classroom setting, can create in-depth connections within the aviation industry (Webb et al., 2018). Students want more platforms and methods to voice their opinions and concerns regarding their education and flight training.

Theme 2: Friendship & Community

Another powerful theme that emerged was friendship and community. There is great power in building a support system among peers. The females in this study felt that building strong friendships and developing a sense of community enable them to be successful in attaining their aviation degree. Peggy stated that, "encouragement from my family, my friends, definitely helped me keep going and helped me stay strong." Many students rely on their friends for moral support and advice on personal and academic decisions (McCabe, 2016). Marge, for example, believes that a strong support system among friends can lead to a higher retention rate. Marge also stated,

> "a lot of influence comes from your friends. But I think the support system for people in the retention rate is very, very important because when you're at a low point in your life, you go to your peers, you go to your friends."

For these female students, the aviation industry is still very much dominated by males; therefore, a strong sense of community within their education institution makes them feel safe and included. Diane further recognized that, "the people around me study very hard, ask questions, help each other, willing to support people around them all." Her community of peers motivated her to persevere through tough courses. Linda confirmed that communities such as

Women in Aviation are "good platforms to find role models like you get to hear stories about like multiple women." For female aviation students, the need for a sense of belonging is considered an important factor for emotional support. Linda also expressed that "being a part of a bigger community where you have people just like you, it's motivating." Mutual goals and aspirations seem to reach out to other students if they are part of a community at a higher education institution.

Theme 3: Positive Faculty Support

The last major theme that emerged was positive faculty support. Females entering the aviation field are initially looking for guidance, someone who can encourage, motivate and talk them through any questions they have. Linda shared,

> I had zero clue of what the aviation industry was like. I just knew I wanted to fly. Having faculty members willing to support my learning needs made training and academics much easier. My faculty advisor made me feel welcomed every time, almost as if there was no gender needs inequality in aviation.

When students find someone they can connect with, someone who is positive and encouraging, they feel more at ease (McCabe, 2016). It appears that female students in aviation at this particular site needed and wanted faculty capable of guiding them through the intricacies of their new experience in a way that is exciting, comforting, and relatable to the aviation industry. Diane explained that "all my aviation professors were caring and friendly. Their genuine desire to see me succeed confirmed that not only was I at the right institution, but also that I chose the right field for me." Providing a sense of direction to female students appears to enable them to take ownership of their academic careers, while boosting their confidence to complete their degree.

All participants highlighted the importance of faculty guidance as it can lead to more opportunities and connections which they think are needed in the industry to succeed. Marge articulated this thought when she explained that her professors "talk a lot about how connections are the way to go and they talked about like the networking side of aviation," which she deemed as an important factor for success. These participants also expressed a clear need for a wide variety of experiences among the faculty as they listen to the stories and the advice from real-life examples. Lois stated that her professors "all had their own experiences with aviation, and they all have a lot of good insight and stories and advice." Despite the research site being aviation-oriented, these participants appreciated the different perspectives gained from a diverse faculty. Faculty support, their knowledge and experiences were mentioned consistently throughout the data set, which shows the importance of this theme as a need and want for minority female students in the aviation.

Limitations

Though conducted with a rigorous qualitative research design, this study was limited by the following factors. First, all participants were from one major aviation higher education institution. Secondly, rather than striving to achieve generalizability in the findings, this phenomenological qualitative research adds extra dimensions and perspectives to the corpus of findings through rich descriptions of the lived experiences of the participants (Creswell & Creswell, 2018; Creswell & Poth, 2018; Moustakas, 1994). Lastly, while this study concedes that the lived experiences of the participants may not reflect the diverse perspectives of female student enrolled in other aviation higher education institutions, it serves as a foundation to study the different perspectives of different student groups in order to better serve future generations.

Conclusion

From the qualitative data collection, three themes were identified which were open communication, friendship and community, and positive faculty support. Based on these themes, it is evident that some minority aviation female students must fulfill their needs and wants in order to complete their four-year degree successfully. The needs and wants can be subjective, depending on the students' strengths and weaknesses as well as their background. In addition, early exposure to aviation, accessibility to female pilots, role models, and their ability to connect with the faculty is critical for attracting and retaining more female minority students. The underrepresentation of minority females in the aviation industry is a systematic issue that will need to be dealt with over a long period of time. There is no overnight solution because the building of respect, trust, and inclusion takes time, especially for the aviation industry, which has been dominantly homogenous for decades. The current female pilot students truly appreciate and respect the beauty and the nature of flying. Furthermore, their biggest motivation for completing their four-year degree is to be able to fly and make flying a life-long career for them. It is crucial that more female students can find interest and willingness to persevere through rigorous and costly flight training in order to benefit from all the opportunities the aviation industry has to offer.

This research focused on the needs and wants of minority women in aviation for them to achieves success and complete their four-year degree. The study conducted individual, semi-structured interviews with students who are currently attending or have attended an aviation-specific HEI in an attempt to explore their perspective of needs and wants. The research focused on two theoretical frameworks; critical race theory and the theory of student attrition. CRT allowed the researchers to explore factors that impact the low achievement of minority students in HEI and possible changes that can improve their learning environment. The student attrition theory added another layer of complexity as it focuses on retention rate of students at HEI and factors that impact it. The research was conducted as a qualitative study as it was the most suitable method of data collection and the delivery of findings. After the data collection and analysis, the results showed that students value open communication, friendship, and community, and positive faculty support. These themes were identified among the six students who have participated in the interview. This qualitative research aimed to provide a better understanding of the needs and wants of minority women within the aviation industry and aviation education. As the number of female pilots in the industry increases, more role models will emerge; representing a more diversified pool of young and experienced aviators.

Recommendations

The increased awareness of racial equality and social justice demands for changes in the HEIs. For HEIs that deal with a low retention rate of minority female students, future studies can explore the effects of faculty's academic support on the retention rates. In addition, similar researches can be conducted focusing on different ethnic or social groups on campus that make up the student body. It is critical to study different perspectives of students in aviation higher education settings in order to better serve the diverse student body. Moreover, some of the best practices that higher education institutions and aviation programs could be adopted from this research are: (1) actively promote and foster a welcoming environment in which students are able to build a strong sense of community, (2) sponsor workshops in which both students and faculty member are able to improve their communications skills, (3) survey students to identify the effectiveness of the faculty support and engagement.

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A Linear Programming Model for Optimal Check Airmen Allocation to Minimize Travel Costs

João S. D. Garcia
Embry-Riddle Aeronautical University

Christian K. Jädicke
Embry-Riddle Aeronautical University

Dothang Truong
Embry-Riddle Aeronautical University

Across the globe, civil aviation authorities (CAA) require pilots to be examined upon completion of their flight training and at regular intervals to uphold their pilot's license. These flight examinations, or checkrides, are conducted by designated flight examiners and CAA pilots. While government employees are dispatched to different locations to conduct such exams, designated check airmen may only conduct checkrides that have limited coverage in the geographic area in which those exams are allowed. Thus, if the demand for checkrides at a given location is higher than the number of available designated flight examiners, those employed by the CAA may have to travel to satisfy the need for checkrides, incurring additional costs to these organizations. This paper aims at developing an optimization model using linear programming to find the optimal number of checkrides at different locations that minimizes the total travel cost of government check airmen (GCA) conducting checkrides, considering specific travel costs between locations. Based on a realistic set of initialization parameters, the optimal solution showed a minimal travel cost of $35,827.30 for six months. This model could be applied to other areas that may face a similar decision-making process.

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Proficiency examinations are constant in a pilot's career, starting with the check flight conducted as a requirement for receiving a private pilot's license. Experienced captains flying international routes for global airlines are also subject to periodic proficiency checks. The International Civil Aviation Organization (ICAO) is the institution responsible for establishing global safety standards for aviation activities (ICAO, 2019). In Annex 1 to the Convention on International Civil Aviation, ICAO requires that all applicants to pilot's licenses "shall have demonstrated a degree of skill appropriate to the license" (ICAO,2011,p. 2-3) or have "demonstrated the skill and knowledge required for the safe operation of the applicable type of aircraft" (ICAO, 2011, p. 2-4). As this is done through a formal examination with regulatory implications, the activity is usually conducted by an employee of the civil aviation authority from the country where the pilot intends to obtain the license, or by a professional accredited by that organization. The use of designated pilot examiners or designated check airmen is common practice in the global aviation industry, and authorities frequently require candidates to provide an excellent safety record as a pilot (e.g., accidents, incident, and violations), to present a reputation for integrity and professionalism within the aviation industry, and to have experience as a flight instructor (FAA, 2018).

CAAs face one issue because the allocation of these scarce professionals is not usually geographically aligned with the demand. One option for authorities to satisfy local demands is to designate pilot examiners to conduct exams in particular locations. If not enough of these professionals are available to satisfy the local demand, the CAA will need to dispatch a government employee to conduct these proficiency exams. Figure 1 provides a graphical representation of the relation between checkrides required and check airmen available. The varying demands of checkrides in the different cities may require the available governmental check airmen to travel, thus generating associated travel cost. Considering that states are continually searching for ways to increase the quality and effectiveness of operations, increased efficiency in travel resources can be relocated to other flight safety assurance initiatives.

To reduce these costs, governments have signed contracts with specific airlines and for specific destinations, such as airfare rates in the City Pair Program (GSA, 2019), which allow secure scheduling of personnel allocation. However, even doing so, travel expenses can be further reduced if the assignment to an exam of personnel from a far home base is reduced. Nonetheless, the requirement for a particular flight examination which demands a governmental check airmen may result in additional travel cost.

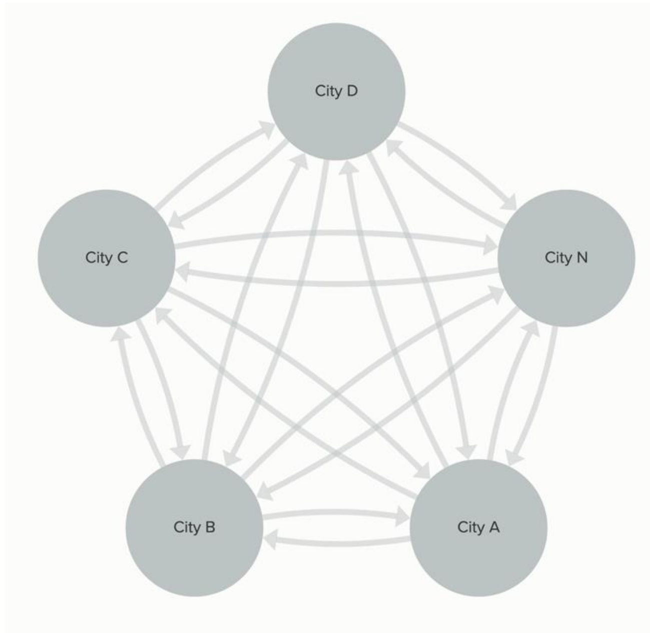

Figure 1. Simplified graph of the relationship between cities (circles) and the distribution of exam-related cost-incurring travels (arrows) for a reduced example set of five cities.

Within the aviation domain, conducting checkrides is a mandatory requirement for flight crew licensing. This task is performed by governmental agencies who either provide or contract the check airmen to administer flight examinations. As the authority responsible for aviation safety within a state, the CAA is responsible for enforcing legal requirements and minimizing associated costs in its operations while optimizing the use of highly-specialized limited-availability personnel. Hence, CAAs have three tasks: satisfying the demand for flight examinations, optimizing the assignment of the available check airmen, and reducing the associated travel costs to the extent possible.

Purpose

This study aims to develop an optimization model using linear programming that addresses the requirement of the CAAs to minimize travel costs while optimizing the allocation of government and designated check airmen. This model's optimal solution can create a comprehensive tool that could be applied in other aviation-related areas involving specialized personnel and the requirement to travel to execute specific demands for activities. This paper's finding provides a tool for decision-making to support the assignment of check airmen to conduct flight examinations at various locations while minimizing the associated travel costs. The provided assignment model offers decision-makers an option to optimize the assignment of key personnel and develop assignment models that consider the average travel costs between city pairs to minimize travel costs. Although developed for air transportation, the model could be applied to other areas that may face a similar decision-making process.

Research Question

The research question investigated in this paper is: Considering the required personnel allocation to fulfill the required proficiency exams at various locations, what is the optimal solution for allocating governmental check airmen to minimize the total travel costs?

Literature Review

The focus of the research presented in this paper lies in optimizing the allocation of check airmen to minimize travel costs. Two main themes can be identified: the allocation of resources and the associated travel or transportation cost. The review of relevant literature includes a short excursion into the subject of flight examination followed by exploring sources addressing the topic of resource allocation. The last part will address the subject of travel costs. The focus will be placed on solving the transportation problem in order to achieve cost minimization.

Flight Examination and Examiners

A flight examination, commonly referred to as "checkride" among aircrews, is part of the regulatory requirements to obtain, regain, or uphold an aviation rating (Flight Examiner, 2019). As such, the aircraft rating supports the capability to legally fly a specific type of aircraft, for instance, single-engine or multi-engine airplanes, seaplanes, or helicopters. Furthermore, additional endorsements may be required, such as high performance, complex, or high-altitude flying operations (Martin, 2016).

Aviation regulations require a flight examiner to conduct the examinations and grant some endorsements. This professional is also referred to as a *check airman*. In general, to qualify as a flight examiner, the applicant is required to provide proof of a minimum amount of total flying hours and an experience as a flight instructor, also measured in flying hours (Central Flight Training, 2019). Detailed requirements to become a flight examiner are provided in the regulatory documents governing flight crew licensing within the respective CAA (FAA, 2019; European Commission, 2011). Although flight examination is a governmental requirement to enforce a standardization level in exams, the flight examiner does not have to be a government employee. Any qualified personnel who is the holder of a flight examiner license can apply to obtain a license as a check airman to conduct checkrides as an associated representative for the respective CAA (European Commission, 2011; Luftfahrt-Bundesamt, 2019).

Resource Allocation

The allocation or assignment of resources can be defined as "the process of assigning and managing assets in a manner that supports an organization's strategic goals" (Rouse, 2014). These resources – also referred to as assets – can be jobs, agents, or contracts assigned to complete a task or achieve the desired result (Anderson, Sweeney, Williams, Camm, & Martin, 2012). Within the business process management domain, human resource (HR) allocation is a crucial element affecting the overall process performance and the result (Arias, Saavedra, Marques, Munoz-Gama, & Sepúlveda, 2018).

At the center of such a process is the respective assignment problem model to optimize resource allocation. It does reflect the requirements to achieve the goal, which is either the minimization or maximization of that objective. A specific characteristic of such assignment problems is that one single asset is assigned to one task at a time (Anderson et al., 2012). This type of resource-task allocation is also referred to as a mono-objective assignment problem (Bouajaja & Dridi, 2017).

In general, the classical allocation or assignment problem can be regarded as a linear problem. If the count of resources matches that of the tasks, the resources and tasks are balanced or symmetric (Bouajaja & Dridi, 2017; Pentico, 2007). If, however, any side constraints are present (e.g., unavailability for travel), the balanced linear problem-solving approach shows susceptibility to these noise factors (Mazzola and Neebe, 1986). When put into relation to the model presented in this paper, the number of check airmen and required checkrides can be described as asymmetric or imbalanced, since the two interacting sets have different proportions (Bouajaja & Dridi, 2017).

Regarding the effect of side constraints, Pentico states that, based on the assumption of any number of given tasks not being accomplished simultaneously, sequencing requirements exist (Pentico, 2007). Concerning allocating check airmen to conduct checkrides, this problem is a factor to be considered as there are considerably fewer HRs than tasks available. In combination with side constraints, for example, “budgetary limitations [or] degree of technical training of personnel” (Pentico, 2007, p. 782), the allocation of the resource can be affected significantly, for example, by the limitation of availability for traveling due to the form of employment (governmental versus designated).

It is critical to minimize the total travel costs while making optimum use of the available check airmen. since there are more checkrides to perform than check airmen are available, the latter constitutes a limiting factor or a bottleneck. Within management science, the bottleneck problem is defined as a limitation imposed on a system’s performance through a single or a limited number of assets (Avudari, 2013). Concerning the presented assignment problem, the classification as a bottleneck assignment problem (BAP) would be feasible, since its goal is to “minimize the maximum of the costs” (Pentico, 2007, p. 777). However, to achieve a BAP solution, a constraint is required, since the “linear programming version of this problem does not guarantee a binary solution” (Pentico, 2007; p. 777).

Travel Cost

Transportation itself describes either the tool to move something from the point of origin to a destination or merely describes the process of moving something between locations. As the presented study addresses the transportation of governmental check airmen from location A to location B, it can be defined as a transportation problem, where “goods and services from several supply locations [are distributed] to several demand locations” (Anderson et al., 2012, p. 256).

According to Kostoglou (2012), a transportation problem requires three sets: capacity, demand, and unit shipping cost. In the present study, capacity is represented by the total number of check airmen available per location. The required checkrides denote the demand, and the unit shipping cost illustrates the travel cost from the point of origin to the destination, limited to the governmental check airmen who can be ordered to travel.

Since the capacity in the current study is comprised of government and non-government check airmen and the demand outweighs the capacity considerably, a simple linear programming model to satisfy supply and demand as described by Anderson et al. (2012) or Kashyap (2017) would be insufficient to formulate the transportation problem. Considering the imbalance and the fact that not all of the check airmen can travel, a potential conflict arises.

An approach to address such an imbalanced constellation with multiple parameters is the bi-criteria transportation problem. A study conducted by Singh and Singh (2018) investigated a multi-objective problem consisting of shipment cost and time required, of which the latter constituted a bottleneck. Applying multiple-choice programming, the researchers found that incorporating multiple-choice parameters resulted in a more flexible transportation model. Concerning the study presented in this paper, the governmental check airmen could function as multiple-choice parameters combined with the associated travel cost from the origin to the destination.

Finally, Bazargan (2010) presents a model for solving crew scheduling problems in airlines. The author argues that flight-crew expenses are controllable and thus subject to airlines' optimization, which could result in significant competitive advantages if adequately addressed. However, such problems' computational costs usually require that it be split into a crew pairing and a crew rostering phase. The crew pairing step yields sequences of flights that start and end at a crew base. While the check airmen problem discussed in the current paper may resemble the crew pairing problem presented by (Bazargan, 2010), decision variables, cost functions, and constraints differ, as check airmen are not restricted by crew duty time limitations and are subject to travel costs, among other differences.

Methodology

Optimization model

An optimization model was developed to support the minimization of travel costs associated with proficiency checks demanded from a CAA by deploying government employees from different geographic locations to complement the checkrides conducted by designated check airmen in each of a set of locations. The parameters used in the model were calculated from information obtained from an imaginary CAA. They included the demand for checkrides in a list of cities and the average prices of flights between cities for six months.

The used parameters were:

- checkride demand in the city;
- average airfare between cities;
- number of available designated check airmen in the city;
- number of available government check airmen in the city;
- maximum number of checkrides per government check airman in the simulated period; and

- the maximum number of checkrides per designated check airman in the simulated period.

Additional constraints for the model included the limitation of the number of active check airmen. Differences between designated check airmen and CAA employees engaged in the activity were also considered, as only the latter is allowed to travel to conduct such exams. In the model, it wasalso considered that, although the current total number of government employees conducting proficiency checks cannot change, the CAA may dispatch them to other locations according to need. One important constraint was the need for all of the demand for checkrides in each location to be satisfied, once upholding their flight currency is essential for pilots, particularly for those flying professionally.

Assumptions and limitations

The LP model's baseline calculations were based on absolute numbers, that is, influencing factors such as leave or illness of check airmen, fluctuating ticket prices, or multiple check rides performed in one day by a single check airman were not considered. Additionally, the historical data used did not specify if every travel was successful, meaning, if the flight examination was performed. Some assumptions were considered in developing the model. The price of air tickets between two cities were considered constant and equal to the average of tickets purchased by the CAA between the same two cities in a particular period. Although this may not result in an accurate representation of the price for a specific flight, these variations tend to have little influence on the average costs in the longer term. Another assumption was that only one exam was performed in each travel and that all government and designated check airmen had a limited number of checkrides they could perform.

Additionally, it was considered that both check airmen were allowed to perform all checkrides. Although this consideration may not hold in reality since some checkrides may need the check pilot to have valid, specific type ratings, the proposed model can be replicated to other sets of categories of type ratings by adjusting the model's parameters accordingly. This adjustment would be facilitated by the simplicity of the proposed model, which resulted in reduced calculation times. However, further enhancements of the proposed model could implement additional complexity in a single run of the calculation, and attention should be placed on the impact on computational costs.

Linear programming model

The proposed linear programming model for the problem is presented below.

<u>Sets</u>
i, j, I: cities i and j in a set of cities I;

The only set considered in the model is that of the cities with information on the local demand for checkrides and government and designated check airmen's availability. This set is referenced as I in the model. A particular city is referenced as i or j, depending on its role as origin or destination in a particular equation.

Decision Variables
$x_{i,j}$: number of checkrides by government check airmen from city i to city j;
y_i: number of checkrides by designated check airmen in city i;

Two main groups of decision variables were used in the model. While y_i represents the number of exams performed by designated check airmen in city i, variable $x_{i,j}$ represents the number of exams performed by government check airmen from city i to city j. While government employees may travel to perform exams in other cities, they can also conduct such exams in their home base without incurring travel costs.

Parameters
CD_i: Checkride demand in city i;
$ATC_{i,j}$: Average ticket cost per ride between cities i and j;
DCA_i: Number of available designated check airmen in city i;
GCA_i: Number of available government check airmen in city i;
$MCRG$: Maximum number of checkrides per government check airman in the simulated period;
$MCRD$: Maximum number of checkrides per designated check airman in the simulated period;

From a total of six types of parameters, three relate to the set of cities I for which the simulation were be run. They included the local demand for checkrides (CD_i) and the number of designated (DCA_i) and government check airmen (GCA_i) for each city i. Additional parameters included the limitations for the number of checkrides each government ($MCRG$) and designated examiners ($MCRD$) could perform and averaged travel costs between two cities i and j. To increase the availability of cost information for all city pairs, the associated costs wereassumed to be the same in both directions ($i \leftrightarrow j$).

Objective Function
Minimize $\sum_i \sum_j x_{i,j} \cdot ATC_{i,j}$
Subject to

$$y_i + \sum_j x_{i,j} = CD_i$$
$$\sum_j x_{j,i} \leq GCA_i \times MCRG$$
$$y_i \leq DCA_i \times MCRD$$
$$x_{i,j},\ y_i \geq 0, \forall i, j \in I$$

The objective function reflects the need to meet the local demand for checkrides in all cities while minimizing travel costs. The total cost is simplified as the sum of the number of flights between two cities multiplied by the average ticket cost. An additional constraint relates to the individual capacity of check airmen. To account for the limitation of personnel, the model considered that the number of travels from city i should be less than the number of government check airmen in that city multiplied by the limit of exams an individual government check airman could perform. A similar constraint was added to account for the number of exams locally designated check airmen could perform. Finally, a constraint was included to ensure that all decision variables were nonnegative numbers.

Data collection

Data generated from six months of demand for checkrides for a set of cities supported the calculation of model parameters, including average flight costs between these different cities and the current availability of government and designated check airmen and their geographic locations. The 26 cities considered in solving the proposed model along with the respective values for parameters CD_i, GCA_i, and DCA_i are presented in Table 1.

Table 1
Cities with Associated Data Regarding Required Checkrides, and Designated and Governmental Check Airmen

City	CD	DCA	GCA		City	CD	DCA	GCA
City A	1	0	1		City N	8	0	0
City B	8	0	1		City O	0	0	1
City C	35	5	10		City P	5	0	1
City D	28	0	7		City Q	0	0	1
City E	18	0	0		City R	13	0	4
City F	1	0	1		City S	3	0	0
City G	17	0	1		City T	73	7	8
City H	16	0	3		City U	5	6	1
City I	5	0	2		City V	8	0	3
City J	3	0	0		City W	173	10	3
City K	22	0	1		City X	2	0	0
City L	9	0	0		City Y	2	0	0
City M	3	0	2		City Z	5	0	0

Note. CD = checkride demand; DCA = designated check airmen; GCA = government check airmen

The demand for check rides was higher in some cities, notably City W, City T, and City C, as visualized in Figure 3. These cities represented the most important economic activity centers in the presented scenario and, thus, presenting more flight training activity. However, the availability of examiners did not necessarily reflect that demand and could bemore elevated where aviation authorities and significant governmental flight departments are located.

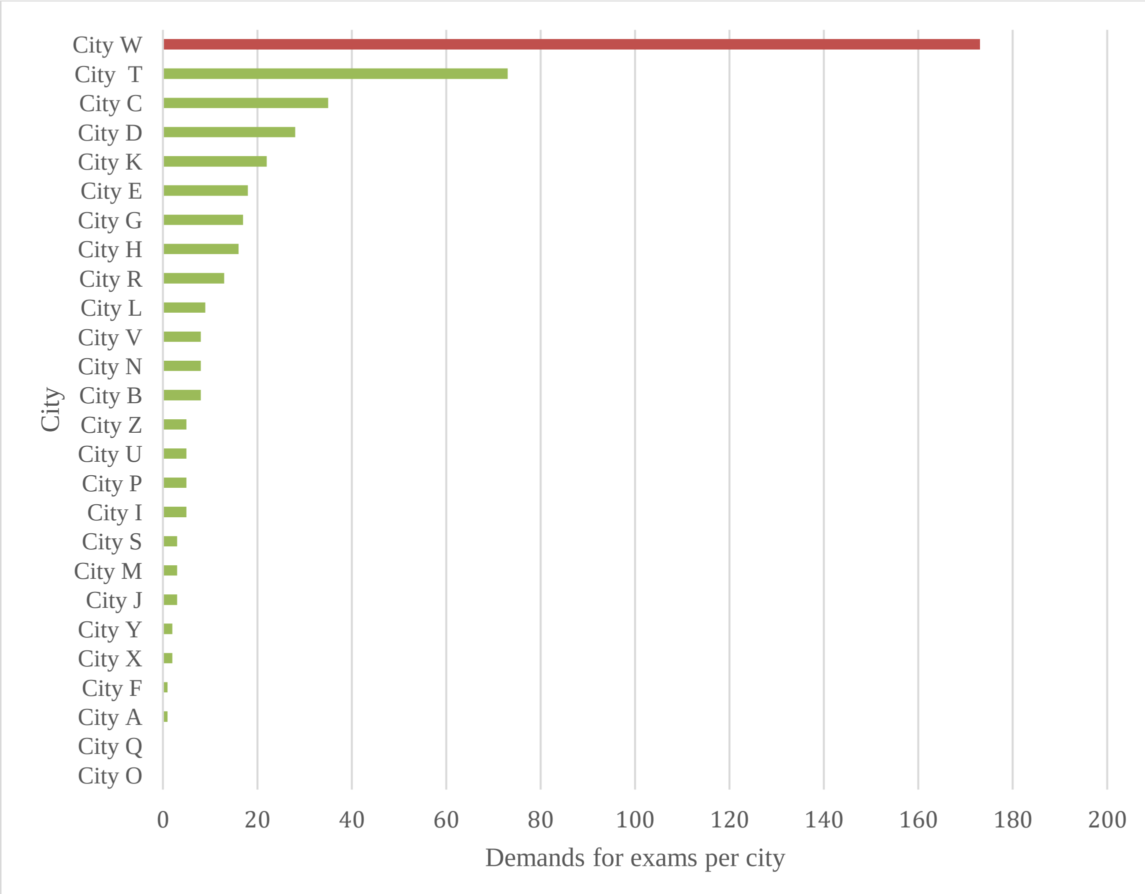

Figure 2. Demand for flight exams in the cities considered for the model.

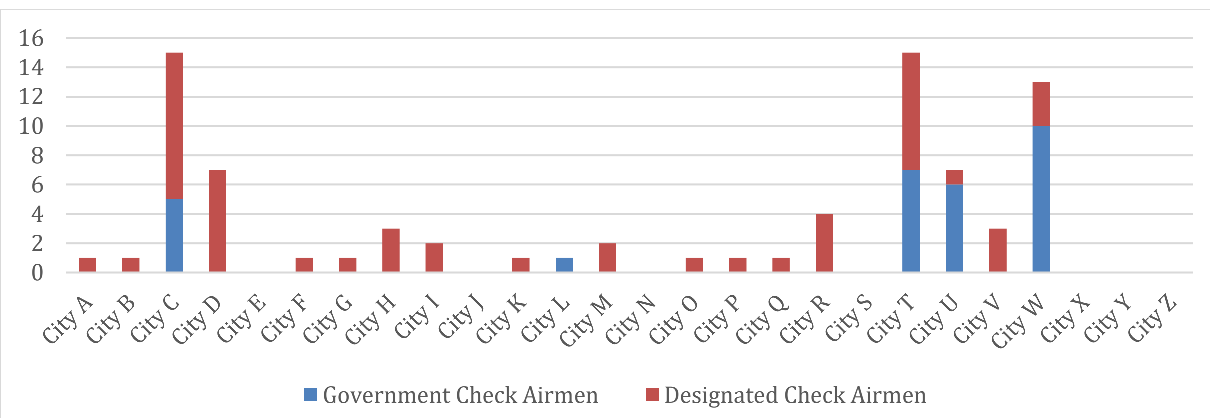

Figure 3. Availability of Government and Designated Check airmen per city in the model.

Solving the linear programming model

The literature supported the development of a Python code used to model the optimization problem. The code utilized an API library for the Gurobi Optimizer 8.1 optimization platform, a mathematical programming solver for linear programming, quadratic programming, and mixed-integer programming problems used extensively by industry (Gurobi Optimization, 2019). Several studies have compared performance among different solvers for mixed-integer linear and nonlinear mathematical optimization problems and included Gurobi in the analysis. Gurobi was consistently ranked highly among competitors due to its CPU-efficiency and has provided significant performance updates in each version update (Anand, Aggarwal, & Kumar, 2017; Jablonský, 2015; Meindl & Templ, 2013; Mittelmann, 2017). It was calculated using Jupyter in a MacBook Pro notebook with 2.9 GHz Intel Core i9 and 32 GB 2400 MHz DDR4.

Gurobi Optimizer's solver indicated that the initial model had 78 rows, 702 columns, and 1404 nonzeros. The solver applies an efficient presolver that reduces unused or redundant variables or unnecessary complexity, which, for the proposed case, removed 64 rows and 660 columns, resulting in a model with 14 rows, 42 columns, and 82 nonzeros. The presolver transforms the original model to a simplified equivalent version, facilitating its computational solution by employing constraint aggregation and reducing sparsity. The optimal solution was obtained in 2 iterations, and both the presolver and solver computations were concluded in under 0.01 seconds.

Results

The proposed model resulted in a practical solution for reducing the costs of the check airman allocation. The application of the proposed model to a set of constraints created from a realistic conjecture of model parameter values yielded a feasible optimal solution while satisfying all of the problem's constraints. The optimal solution resulted in a total travel cost of $35,827.30, meeting the demand for 463 exams in all 26 cities. Locally designated check airmen conducted a total of 298 exams while government employees performed 165 checkrides. Local exams conducted by government employees in City W accounted for 113 exams. Table 2 presents the non-zero values.

Table 2
Nonzero results of checkrides flown by government check airmen after applying the linear programming model

Variable	**x**	**Variable**	**x**
$y_i[City\ A]$	*1*	$y_i[City\ V]$	*8*
$y_i[City\ B]$	*8*	$y_i[City\ W]$	*60*
$y_i[City\ C]$	*35*		
$y_i[City\ D]$	*28*		
$y_i[City\ F]$	*1*	$x_{i,j}[City\ C, City\ K]$	*2*
$y_i[City\ G]$	*17*	$x_{i,j}[City\ C, City\ Y]$	*2*
$y_i[City\ H]$	*16*	$x_{i,j}[City\ L, City\ L]$	*9*
$y_i[City\ I]$	*5*	$x_{i,j}[City\ T, City\ N]$	*8*
$y_i[City\ K]$	*20*	$x_{i,j}[City\ T, City\ S]$	*3*
$y_i[City\ M]$	*3*	$x_{i,j}[City\ T, City\ Z]$	*5*
$y_i[City\ P]$	*5*	$x_{i,j}[City\ U, City\ E]$	*18*
$y_i[City\ R]$	*13*	$x_{i,j}[City\ W, City\ J]$	*3*
$y_i[City\ T]$	*73*	$x_{i,j}[City\ W, City\ W]$	*113*
$y_i[City\ U]$	*5*	$x_{i,j}[City\ W, City\ X]$	*2*

Note. x = number of checkrides; $x_{i,j}$ = number of checkrides by government check airmen from city i in city j; y_i: number of checkrides by designated check airmen in city i

The results mentioned above indicated lower ticket prices leaving from City C, City T, and City W favor dispatching government employees from these locations to different cities to perform exams. This finding supports results that show significant slack in several locations, both for the government and designated check pilots. This result is indicated in the shadow price and slack information obtained in the calculations for all three constraints reflecting demand (CD) and government (GCA) and designated check airmen (DCA) limitations. These sensitivity measures indicated the model calculation to be robust to changes in parameter values, but also reflected that the check airman allocation and resulting costs depend heavily on $ATC_{i,j}$, which should receive proper consideration in the model parameter setup. For instance, noticing the higher travel costs to City L, a new simulation was run considering the designation of an additional government check airman to the city. As a result, the total cost was reduced significantly compared to that in the standard scenario to $17,827.30. This finding indicates the versatility of the model supporting decision-makers by facilitating prospecting scenarios and opportunities for gains in efficiency.

Discussion

The linear programming model application using the Gurobi optimization algorithm to an instantiation of the proposed problem provided a single optimum solution, fulfilling the requirement to conduct checkrides in all locations. Considering the parameters presented in the previous sections, the results presented in Table 2 illustrate that the demand constraint pressures total cost for the model in seven cities, with City L, City N, and City Y representing higher costs, and should demand an increase in check airmen allocation in these locations. When assessing the sensitivity metrics associated with the constraint, it should be noticed that some locations such as City C (91 for GCA;165 for DCA), City D (0; 112), City T (120;87), and City U (120;15) present significant levels of slack concerning the limitation of personnel. As mentioned previously, City L, City N, and City Y are examples of locations not supplied with enough local examiners, which pressure total costs for the model.

The review of the defined constraints allows the argument that, concerning the qualification of the check airmen, no differentiation regarding the type of airframe was made. The result of such constraint would be a possible change in check airmen allocation to assign the adequately qualified person to conduct the corresponding checkride. This argument can be countered with the assumption that flight examiners can conduct checkrides for multiple aircraft types. Nonetheless, implementing such a constraint would add to the robustness of the proposed model since it would constitute additional decision variables in the model.

Regarding the data used to develop the minimization model, it could be argued that it is non-representative as it was limited to a particular CAA's method of dispatching examiners. Although this observation is correct, one must consider that the mix of dedicated and government check airmen is not a localized phenomenon but common practice around the globe. However, there may be differences between CAAs regarding the number of available government check airmen and the regulations governing their travel. Applying the proposed model would, therefore, produce adequate results.

Conclusions

This study proposed the application of an assignment and transportation linear programming model using the Gurobi optimization algorithm. It was developed to provide a solution to minimize travel costs of check airmen operating in a CAA's area of responsibility. With a defined set of decision variables and constraints based on available data, the model application for check airmen resulted in an optimal solution. This means that the application of the model to other sectors of general aviation could produce relevant results. Through manipulations of the constraints, the decision-maker could also define requirements regarding the number of necessary check airmen.

Although using a simplified approach by observing only the constraint of being able to travel or not, the proposed model has been successful in minimizing the travel cost through optimization of check airmen allocation. Therefore, the presented LP model offers decision-makers in aviation authorities an easy-to-use tool adaptable to accommodate similar situations such as the presented one. The combination of optimizing the use of human resources and minimizing the related-travel costs will allow the efficient and responsible use of two commodities that lack abundance. If additional resources are available for hiring additional government check airmen, rerunning the simulation indicates that City L would be the right place for that resource to be placed. Adding the new post there would reduce the total costs significantly.

Recommendations

Similar data from different CAAs should be used to create a basis for comparison to validate the applicability of the proposed model. Furthermore, to improve the robustness and adaptability to various scenarios, the implantation of additional constraints affecting the assignment process could be beneficial. At the same time, more detailed information would be required regarding the check airmen qualification and type of airframe on which the checkride must be conducted.

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Utilizing Flight Data Monitoring for Near Miss Incident Analysis

Samuel Pavel
Southern Illinois University

Bryan Harrison
Southern Illinois University

Ken Bro
Southern Illinois University

Avinash Sorab
Southern Illinois University

Michael Robertson
Southern Illinois University

Midair collisions (MACs) and near midair collisions (NMACs) have been a concern for pilots and regulators since the advent of flight and the creation of the national airspace system. The purpose of this paper is to explore novel analysis methods for determining and representing near miss events at a collegiate flight school utilizing standard Garmin G1000 avionics data logging. The analysis of near-miss geographic distributions revealed useful trend information that has been used systemically to reduce the number of near-miss events, by way of discussion with instructors and implementing congestion limits or traffic area dispersal. The next iteration of data modeling would benefit from heatmapping, to identify trending geographic near-miss areas in near real-time.

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Midair collisions (MACs) and near midair collisions (NMACs) have been a concern for pilots and regulators since the advent of flight and the creation of the national airspace system. Like most aircraft accidents, MACs are preventable through awareness of *human causal factors* such as improvement in *pilot education, operating practices, procedures, and techniques* (FAA, 1970). Unlike most aircraft accidents, MACs are almost always fatal. Most MACs occur during daylight hours in VFR conditions and within just a few miles from an airport. Because of this, midair collisions are considered one of the most feared types of accidents in the flight training environment. Midair collisions were the tenth leading cause of fatal accidents between 2001 and 2013 (Ulrich and Wild, 2015).

The purpose of this paper is to explore novel analysis methods for determining and representing near miss events at Southern Illinois University Carbondale (SIUC) utilizing standard Garmin G1000 avionics data logging. The use of Flight Data Monitoring to assist in mitigating the risk of MACs within the Safety Management System will also be discussed.

Background

The first attempts to reduce the possibility of MACs and NMACs in the 1920s were controllers such as Archie League in St Louis who communicated with pilots by waving flags. The Federal Government created an Aeronautics Branch in the Department of Commerce in 1926 to address aviation safety, including the establishment of a national airway system and enforcement of air traffic rules. The first en route air traffic control (ATC) centers were established by the airlines in 1934 to prevent aircraft collisions. The new ATC system failed to prevent 65 MACs between 1950 and 1955 due to its limitations in segregating VFR and IFR traffic. The most high-profile midair collision occurred over the Grand Canyon in 1956 when two airliners collided, killing all aboard. This collision led to the creation of what is now known as the Federal Aviation Administration and improvements in ATC that significantly reduced MACs and NMACs in the national airspace system (FAA, 2019).

Even with the increased vigilance provided by ATC services MACs and NMACs continued to occur. In 1968, there were 2,230 NMACs reported to the FAA and 38 MACs. Of the 38 MACs more than half occurred in the traffic pattern at an airport, with a large majority of these accidents occurring at an airport without an operating control tower (FAA, 1970). This prompted the FAA to release Advisory Circular (AC) 90-48 - Pilots' Role in Collision Avoidance to help mitigate the occurrence of MACs and NMACs (FAA, 1980).

The advisory guidance from the FAA continued to evolve with AC 90-48A issued in 1979 after there were 34 MACs resulting in 190 fatalities in 1978 (FAA, 1979). Another revision issued in 1980 (AC 90-48B) to re-emphasize the role of the pilots in preventing MACs. In 1983 AC 90-48C was published even though the occurrence of MACs reduced from 38 to 25 annually by 1981, NMACs increased to 2,241 between 1978 and 1982 (FAA, 1983). Over time as new technology was introduced and pilot awareness of MACs and NMACs increased, the rate of MACs and NMACs reduced significantly by 2013. Between 2009 and 2013 there were only

42 MACs and 461 reported NMACs. In 2016 AC 90-48D was published incorporating specific pilot scanning techniques, procedures, and collision-avoidance technologies to help further reduce the occurrence of MACs and NMACs (FAA, 2016).

Traffic pattern entry at non-towered airports has been a key factor in reducing aircraft accidents because most MACs and reported NMACs prior to the year 2000 occurred at airports without an operating control tower. Many flight training programs are located at airports without an operating control tower are keenly interested improving procedures and training that will mitigate the possibility of MACs and NMACs. Teresa Sloan at Central Washington University conducted a survey of flight instructors attending Flight Instructor Refresher Courses in Washington State in 1999 and 2000 (Sloan, 2000) to find out if flight training of procedures of flight pattern entry an non-towered airport contributed to the problem. Sloan was particularly interested in the way flight instructors trained pilots to enter traffic patterns at airports without an operating control tower. What she found out was there was no standard method of entering traffic patterns being taught. In fact, several frightening trends were identified in training that would actually increase the risk of a MAC. Sloan concluded that until the FAA publishes an AC on entering traffic patterns at non-towered airports pilots need to comply with the FAA's Aeronautical Information Manual and existing Advisory Circulars (Sloan, 2000).

In 2019 researchers at Liberty University and the AOPA Air Safety Institute published the results of their study of fatal accidents in the flight training environment (Walton, Bauman & Geske, 2019). They found between 2000 and 2015 there were 240 fatal accidents involving flight training aircraft, although the accident rate deceased 35% over then time period of the study. The majority (54%) of the accidents were loss of control inflight. Ten percent (10%) of the accidents were MACs. Overall, MACs decreased between 2000 and 2015 which they attribute to the use of traffic awareness technology, deconflicting practice areas, and use of ATC flight following (Liberty, 2019). They also found MACs at airports without an operating control tower has reduced significantly from earlier studies. Of the 24 fatalities from MACs 71% occurred outside the airport environment, 32% occurred in Class D airspace, and only 8% occurred at non-towered airports.

Since 2015 there have been 2 fatal MACs involving aircraft used in flight training (NTSB, 2019). One occurred at an airport without an operating control tower and the other occurred 9 miles northeast of an airport with an operating control tower. In the case of the MAC outside of the Class D airspace one aircraft was in contract with ATC and had been issued a traffic advisory.

The 2019 Liberty/AOPA study stated that deconflicting practice areas was a factor in the reduction of MACs involving training aircraft. Although not defined in the report, deconflicting practice areas implies there would be less flight training in a particular area and therefore the probability of a MAC would be reduced. However, would the reduction in MACs be simply based on a simple reduced frequency probability of two aircraft colliding because of the reduced number of flight training aircraft in the area? Do NMACs still occur and at what frequency? To help answer this question, researchers at SIU Aviation at Southern Illinois University Carbondale have developed a methodology using Garmin G-1000 avionics data to determine whether NMACs occur, even in deconflicted practice areas. This data analysis technique will give flight schools another tool to further reduce the possibility of MACs and increase the safety of flight training programs.

Methodology

A near miss, for this research, is defined as two or more aircraft being within 500 feet, absolute distance, excluding aircraft-on-ground. Using this definition, a query of all the department's flight data is performed to determine local time, aircraft identification, and positional information. The data is represented in various formats (satellite-view map, closure-rate chart, and histogram) for different analytic purposes.

In defining a near miss with absolute distance, three coordinate positions are compared across the aggregate of all flight data. To determine the absolute distance between any two aircraft, the following simple Euclidean representation is used (Figure 1).

$$Distance = \sqrt{\sum |Latitude_1 - Latitude_2|^2, |Longitude_1 - Longitude_2|^2, |Altitude_1 - Altitude_2|^2}$$

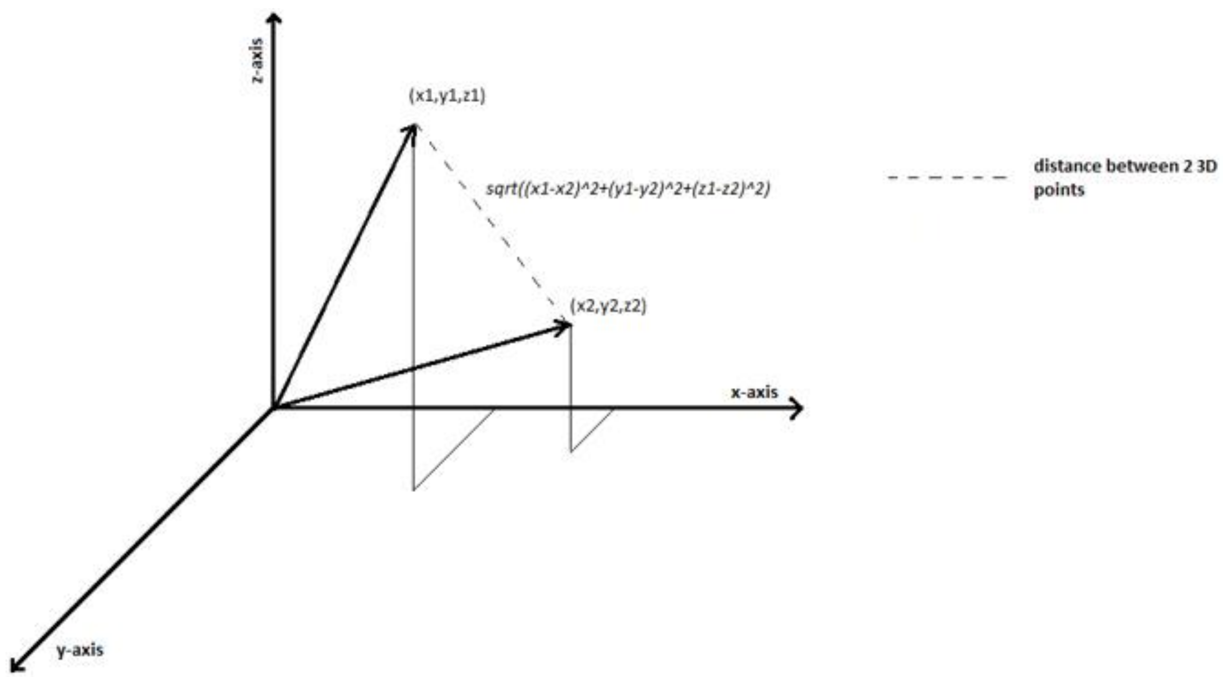

Figure 1. Calculating distance between two points in Euclidean space.

For the purposes of this research the curvature of the earth is ignored; latitude and longitude are treated as conserved values. To efficiently determine absolute distance between aircraft, longitude and latitude are treated as conserved quantities (no haversine adjustment is made). If a greater degree of accuracy is required (aircraft flying at higher latitudes), the Haversine formula or equivalent could readily be utilized. Since the aircraft in this dataset remain within a few hundred miles of the origin latitude, the proximal figures will remain accurate within a small percentage.

To exclude aircraft-on-ground efficiently from the search query, it is assumed that an aircraft is flying based on an airspeed value greater than 25 knots. In using this airspeed, an aircraft approaching a runway where another aircraft is holding short is excluded, two aircraft taxiing or parked are excluded, and only aircraft-in-air have been captured. Potential limitations to this assumption include high-speed taxis, in which an aircraft taxiing greater than 25 knots parallel to an aircraft landing could be captured. However, there is utility in keeping the exclusion value close to 25 knots, such that a high-speed turnoff with aircraft in close proximity, or a close go-around with an aircraft on rollout could be captured , although this event has not yet been seen in the data.

Initial Modeling Framework

In the first attempt at data query, a local workstation and SPSS were utilized. Runtimes with a large (10GB) data set are in the multiple-hour range, and not pragmatic for routine data analysis. In this method, individual events are identified as cases of CSV data, which require further efforts to represent visually. In this first iteration, the cases are converted to KML files using proprietary VB scripts to visualize flight paths in Google Earth. This representation is satisfactory, although it is requiring substantial human resources to produce appropriate visuals for a large data set. See original framework below in Figure 2.

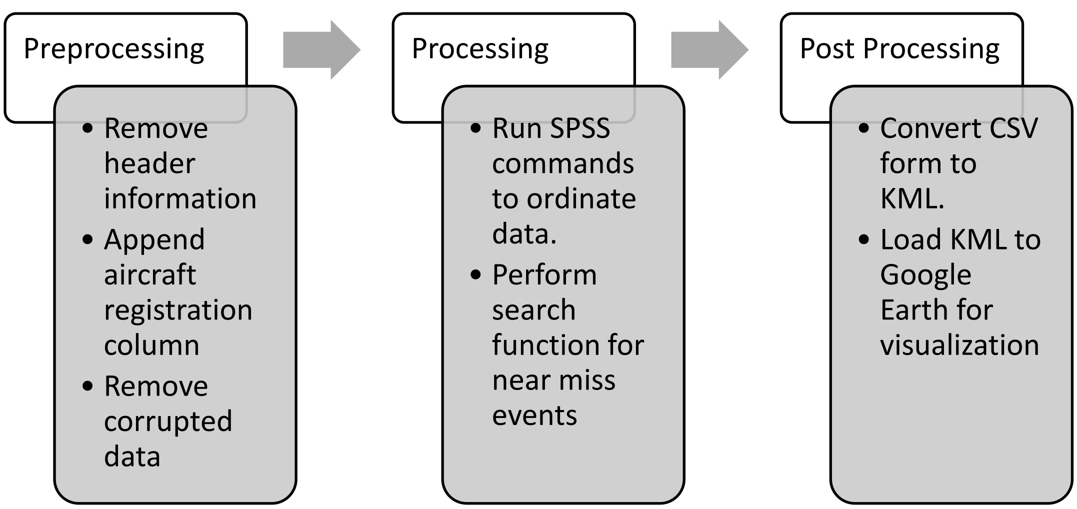

Figure 2. Original framework for near-miss analysis.

Revised Modeling Framework

In the second and current generation of data query (Figure 3), an entirely new approach was utilized. First, to improve run-time, cloud storage and computing is utilized. Multiple vendors were investigated to assess cost, CPU availability, and server-side analysis tools. Google Cloud, Big Query and Cloud Compute constitute the primary cloud resources. These tools also offer the ability to integrate neatly with various visualizations.

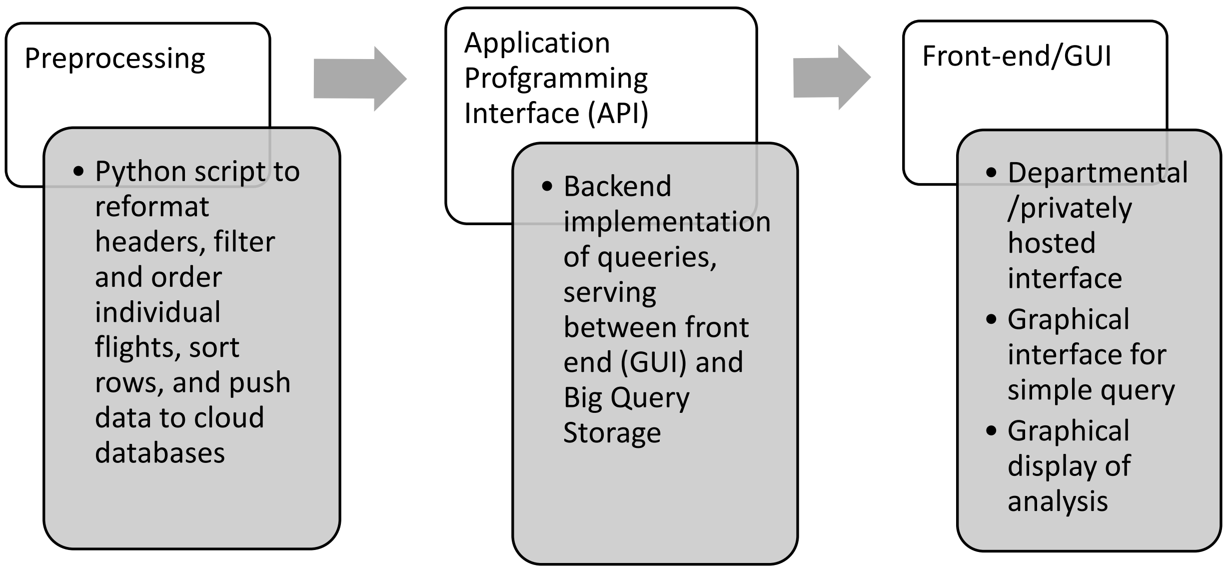

Figure 3. Improved framework for near-miss analysis and representation.

An important feature to promote departmental use of the analysis is the front-end application. The current iteration is a departmentally-hosted website that affords various stakeholders the ability to run data in near real-time. With this interface, once data is uploaded to the cloud users are able to quickly perform various analyses and are provided with user-friendly graphical displays.

As shown in Figure 4, two aircraft converge on an approach to the airport's Runway 18R. The aircraft represented by the blue line is converging with the aircraft on final, shown in red. To capture enough data to visualize an event like this, when a near-miss is discovered, the visualization will also include a few seconds before and after the proximity trigger.

Figure 4. Map-view of two aircraft converging. Note: Identifying data (Aircraft Registration) removed.

A typical near-miss proximity chart should be a parabolic curve, indicating a convergence (negative slope, left of vertex) then divergence (positive slope, right of vertex). The steepness of the curve left of vertex indicates the closure rate. Zero slope, or a flat line, indicates aircraft typically in formation, where absolute distance is roughly constant for some time. Often the slope to the right of the vertex is steeper, indicating a maneuver performed to increase the rate of divergence (Figure 5). As with the map-view, it is important to include a few seconds before and after the data meeting the definition of near miss, to contextualize the analysis.

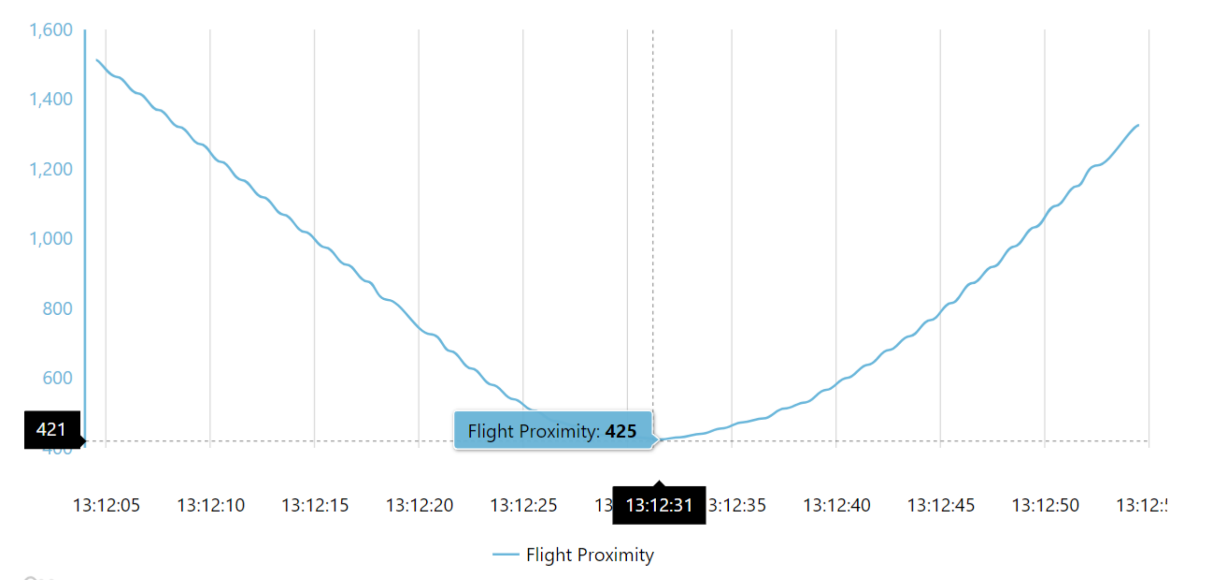

Figure 5. Proximity Visualization. Absolute distance represented by Y-axis, and time the X-axis.

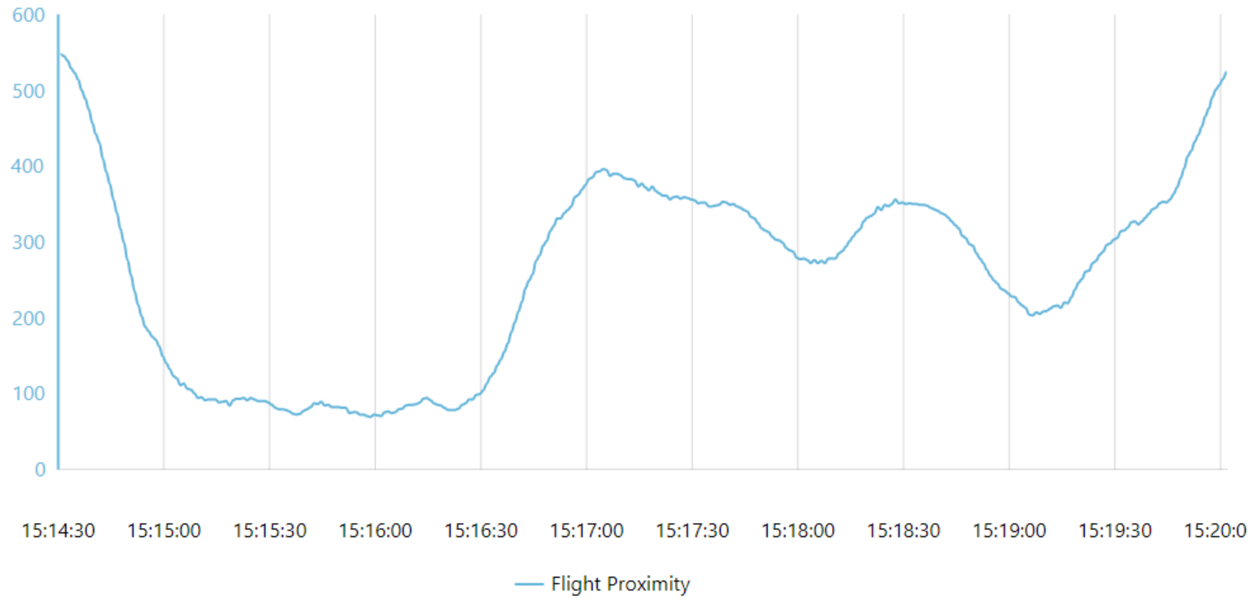

Figure 6. Atypical proximity distribution.

Limitations

While data modeling provides many opportunities for identifying near misses in the past, there are limitations with the collection and timely processing of data. Currently, only eight training airplanes are equipped with avionics (G1000, G500) capable of gathering accurate position data. At present, near midair collisions can only be identified when two or more of these aircraft are involved in the NMAC event.

At present, data cards of the training airplanes are only analyzed every two weeks causing a lag in the timely analysis of data. ADS-B data could be processed nearly instantaneously and cover all training airplanes, though is not feasible due to poor low-altitude ADS-B coverage in southern Illinois.

Conclusions & Future Development of Data Monitoring

A Flight Data Monitoring (FDM) program has the goal of improving the safety of the flight training environment. FDM is a key process within a Safety Management System (SMS) and the Safety Assurance component. The procedure for data collection is as follows: An FDM analyst removes the SD cards of the G1000 equipped aircraft two times per week during the semester. The FDM analyst will upload the data for analysis. The data is collected by the SMS Coordinator and is Reviewed by the Safety Review Committee (SRC). It is the responsibility of the FDM analyst and the Safety Review Committee to keep all recorded flight data under the FDM program confidential. The SRC will review FDM reports and make procedural or program changes to the Chief Flight Instructor and Accountable Executive if applicable.

Post-hoc metanalysis of near-miss geographic distributions reveals useful trends—the near miss events occur primarily in the traffic pattern, secondarily at a neighboring airport, and tertiarily in specific practice areas. To date, this distribution has been used systemically to reduce the number of near-miss events by way of discussion with instructors and implementing congestion limits or traffic area dispersal. The SRC and SMS Coordinator continually monitor the data so that continuous improvement within the SMS takes place and the risk of an MAC is as low as possible.

The next iteration of data modeling would benefit from heatmapping to identify trending geographic near-miss areas in near real-time. This can be accomplished as more airplanes are upgraded to advanced avionics or with better ADS-B coverage of the practice areas.

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From Classroom to Industry: Human Factors in Aviation Maintenance Decision-Making

Bettina Mrusek
Embry-Riddle Aeronautical University

Stephanie Douglas
Embry-Riddle Aeronautical University

The presence of human factors in aviation remains a critical area of research given the safety implications of human error. Understanding what specific factors contribute to human error allows managers and operators to take steps to mitigate these hazards. Several methods have been tested in the cockpit and cabin crew environments, but less attention has been given to the aviation maintenance sector, despite the prevalence of accidents resulting from human error. With the introduction of AC-172A, the FAA validated the need for additional research and training on the role of human factors in aviation maintenance errors. However, a key component in this process is often overlooked--the role of decision-making. In aviation maintenance, the environment can change rapidly. Technicians must react and adjust their behavior, and their decision-making abilities, accordingly. Human factors such as fatigue, pressure, and distractions can interrupt cognitive processes and judgment, and in turn, decision-making. As technicians adapt to these environmental challenges, strategies must be in place to facilitate optimal decision-making. Recommendations for addressing the presence of human factors in aviation maintenance and the resulting impact on the decision-making process include taking both a proactive and reactive approach to human error identification. Proactively screening for individuals who are too risk-averse or too comfortable with taking risks can help hiring managers employ the right personnel equipped to make appropriate decisions in high consequence industries, such as aviation. Additionally, by encouraging and reviewing hazard reports, steps can be taken to mitigate human error factors in the future. Anonymous hazard reporting tools such as the REPAIRER allow maintenance managers to leverage existing (and FAA-required) safety management systems (SMS) by including a human factors analysis.

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Recently, there has been a greater emphasis on the role of human error in aviation accidents, namely those that can be attributed to aviation maintenance errors (Rashid, Place, & Braithwaite, 2013). While there are general guidelines that organizations can utilize to mitigate the presence of human error in these environments, less attention has been given to the unique challenges present in an aviation maintenance environment such as troubleshooting. This investigative process of determining the underlying cause of a maintenance failure can be time-consuming and costly but is also accompanied by pressure constraints during aircraft on ground (AOG) scenarios or those in which there is a serious maintenance problem that is preventing the aircraft from flying. During these times, technicians can face incredible pressure to complete tasks as quickly as possible. To address potential safety hazards in aviation environments the FAA requires systematic procedures, practices, and policies, also known as Safety Management Systems (FAA, 2020). These programs support safety practices by viewing safety from a holistic perspective as opposed to merely a reactionary one. In practice, SMS systems provide an architecture for aviation organizations to proactively manage safety (Stolzer, Friend, Truong, Tuccio, & Aguiar, 2018). In aviation maintenance environments, however, the decision-making process that occurs while troubleshooting AOG aircraft or other high-pressure scenarios has not been fully explored. While Aeronautical Decision-Making has proved effective in the cockpit (Harris & Li, 2016), its application to the aviation maintenance environment could similarly prove useful especially when incorporated into training environments. This concept, combined with effective hazard reporting tools, could improve the effectiveness of FAA-mandated SMS programs in an aviation maintenance environment.

Background

Human error accounts for nearly 80% of all major Federal Aviation Regulation (FAR) Part 121 accidents (Marais & Robichaud, 2012). Much research has been done to address this problem, with most efforts focused on the cabin and cockpit environments (Bienefeld & Grote, 2014; Ford, Henderson, & O'Hare, 2014; Peksatici, 2018). However, human error extends beyond the internal environment of the aircraft. Aviation maintenance crews also contribute to this percentage, although there is much less research to support this segment of the industry. While efforts have been made to improve the safety culture, a key component in this process is often overlooked; the decisions made during the troubleshooting process. Problem-solving in aviation maintenance is not strictly a linear process. In many cases, multiple decision points are considered throughout the troubleshooting process, which when coupled with the presence of one or more precursors to human error, can create a potentially unsafe environment (Rashid, Place, & Braithwaite, 2013). The Dirty Dozen or the twelve most common precursors to human error in aviation maintenance (Dupont, 1993) is widely known and researched in aviation as well as other high-consequence industries (Marquardt, Treffenstadt, Gerstmeyer, & Gades-Buettrich, 2015; Samad, Johari, & Omar, 2018). However, the extent to which these occur throughout the troubleshooting process has not been fully explored. Given the lateral nature of the decision-making process and the livewire component of the aviation maintenance technician, strategies that minimize human error must be developed which account for variations in the decision-making process. Discounting these elements may conceal the root cause of the error. In this research paper, the authors will examine how the presence of human factors affects the decision-making process in aviation maintenance and provide recommendations for improving this process thus creating a more robust safety culture within the aviation maintenance environment.

Human Error and the Aviation Maintenance Environment

Aircraft accidents are an unfortunate reality in the aviation industry. While significant efforts have been made to increase safety at all levels of the industry since its inception, accidents still occur. As previously noted, human error accounts for nearly 80% of Federal Aviation Regulation (FAR) 121 Category aviation accidents, 10% of which can be attributed to aviation maintenance (Marais & Robichaud, 2012). While this number may seem insignificant, as demand for air travel grows, the pool for which this percentage is derived will be much larger, validating the need to identify root causes and mitigation strategies for human error in aviation maintenance. While research has been conducted on this topic, they are often reactive, such as the National Transportation and Safety Board (NTSB) investigative reports. The NTSB performs official investigations on all aircraft accidents which has created a wealth of information researchers and industry personnel can use to modify or amend safety protocols. The information can be filtered by aircraft type, injury, or fatality numbers, as well as the underlying cause for the accident/incident (United States of Department Transportation, 1926). Over the last several years, the role of human error in accident causations has risen to the top (Marais & Robichaud, 2012; Rashid et al., 2013). The distribution of this error has become an area of concern in the aviation industry, given its direct impact on overall safety. Empirical research studying aviation maintenance errors completed by Graeber and Marx (1994 noted four key categories of maintenance errors: omission (56%), incorrect installation (30%), wrong part (8%), and other (6%). Other studies yielded similar results regarding common causes of maintenance errors in aviation (Latorella & Prabhu, 2000; Prabhu & Drury, 1992).

Other research areas include the Dirty Dozen, Safety Management System programs, and Maintenance Human Factors, or MxHF (previously referred to as Maintenance Resource Management [MRM]). The *Dirty Dozen*, or the twelve most common precursors to human error in aviation maintenance, were identified by Gordon DuPont (1993) as a means of identifying preconditions that are most likely to result in human error. While there are certainly other conditions that could increase the likelihood of human error, these twelve were found to be the most common in aviation maintenance (Dupont, 1993). The original intent, which still stands today, was to bring awareness to how maintenance technicians contribute to accidents. The FAA along with the International Civil Aviation Organization (ICAO) has published guides as well as online training courses to support and educate aviation organizations in proactively identifying the twelve preconditions for unsafe acts (FAA Safety Team, n.d; ICAO, 1993).

A well-known proactive approach to managing safety in aviation is the Safety Management System (SMS) programs (Kearns & Schermer, 2017; Stolzer, Friend, Truong, Tuccio, & Aguiar, 2018). The FAA defines SMS as the "formal, top-down, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls. It includes systematic procedures, practices, and policies for the management of safety risk" (FAA, 2020 pg A-2). SMS programs are comprised of four main components: safety policy, safety risk management, safety assurance, and safety promotion. Each area focuses on a different element of safety, promoting safety through organizational policies, proactively identifying risk hazards, then having programs to monitor and promote a safety culture. Combined, these elements form the foundation for a safety culture that proactively identifies and minimizes risk. However, only recently has the inclusion of human factors been included in SMS studies. Miller and Mrusek (2018) designed a hazard reporting system that fulfilled the FAA SMS requirements, while also accounting for the role of human factors, such as the Dirty Dozen in an aviation maintenance environment. As leaders in the aviation industry work to mitigate the hazards associated with human error, existing SMS programs present a viable opportunity given that they are already in place, and required by the FAA (FAA, 2020).

In 2017, the Federal Aviation Administration released an update to Advisory Circular (AC) 120-72, Maintenance Resource Management (MRM), which expanded traditional MRM concepts of effective communication and safety to include human factors (FAA, 2017). The new AC, appropriately titled Maintenance Human Factors Training, emphasizes training aimed at minimizing precursors to human error. While informative, the document serves as a guide only and is not as a mandatory requirement. On the surface, the inclusion of human factors training into existing safety management systems (SMS) would address the operational safety hazards found in an aviation maintenance environment.

Given that in 2012 10% of all FAR 121 accidents were attributed to aviation maintenance errors (Marais & Robichaud, 2012), it is clear that while the types of causes have been identified, the errors themselves remain today. This raises questions regarding the decision-making process that occurs before and following the improper maintenance actions. While aviation safety has improved substantially over the last several decades (Madsen, Dillon, & Tinsley, 2016), some elements continue to pose hazards, such as the occurrence of aviation maintenance errors and the role of decision making in that process. If this element could be better understood, steps can be taken to ensure the right decisions can be made.

The Decision-Making Process

High consequence industries are those in which human life or quality of life is at stake. In industries such as aviation and health care, even routine decisions can be the difference between life and death. The decision-making process for those that work in these industries, therefore, is crucial. To improve the safety of these industries, regulatory agencies outline guidelines and provide resources to improve safety standards. In the U.S. aviation industry, the Federal Aviation Administration is responsible for setting such standards. While significant progress has been made in pilot training and aircraft equipment and systems, accidents still occur. The common factor among these accidents is human error (Latorella & Prabhu, 2000). Despite advances in technology, the human element in aviation cannot be eliminated. Instead, a proactive approach to mitigating human error must be taken (FAA, 2017; Latorella & Prabhu, 2000). Examining the decision-making process for personnel in high consequence industries, such as aviation, could uncover root causes in judgment errors.

The concept of naturalistic decision-making (NDM) process is often utilized to replace the simplistic, sequential decision-making process. In contrast to decision paradigms that used pre-defined tasks given under controlled environment, NDM examines decisions made over time under natural conditions, relying on experience to cope with challenging decisions. NDM is most often applied to those occupations considered high consequence. In using a continuum of processes to adapt effectively to environmental constraints and the differing levels of ability among decision-makers, the NDM continuum ranges from an analytically based decision process to one more grounded in intuition (Klein, Oransanu, Calderwood, & Zsambok, 1993). Various models have been developed in NDM from the Kleinst al. (1993) process-driven recognition primed model which describes how situational cues are used to identify patterns from previous experiences and then are used to construct patterns to make sense of the world around them. Pennington and Hastie (1986) decision model is an explanation based where the role of situation assessment and recognition will predict how decisions are made in situations in which there is incomplete information. Finally, Rasmussen's (1983) decision process model of typological cognitive control identifies different types of behavior to show the influence of individual values and goals in addition to habit and automaticity will influence decisions. The various models of NDM consistently identify decision making is not done or influenced by discrete isolated events or processes and situation assessment is essential.

Various factors contribute to behaviors in decision making. Understanding the context surrounding the decision is a key part of the process as is understanding how individuals function in their decision making. The emphasis in NDM is on the decision-maker to objectively assess situations versus the role of affect regulation on the decision-making process. Affect regulation is the ability of an individual to modulate their emotional state to adaptively meet the demands of their environment (Schore, 1994). Understanding how this influences decision-making is essential. In aviation maintenance, the environment can change rapidly. Personnel must react and adjust their behavior, and ultimately their decision-making abilities, accordingly. The Dirty Dozen identifies precursors to human error aviation that may stem from affect regulation. Fatigue, pressure, distractions, and stress are identified as emotional factors resulting in physical or mental tension. Such factors can interrupt cognitive processes and judgment pertinent to decision making (Chan & Singhal, 2013; Lazarus, 1991).

Aeronautical Decision Making

Recognizing the need for a systematic approach to decision-making in aviation, the Federal Aviation Administration published an advisory circular (AC 60-22) on Aeronautical Decision Making (ADM) (1991). The FAA defines aeronautical decision making (ADM) as a “systematic approach to the mental process of evaluating a given set of circumstances and determining the best course of action” (FAA, 1991, pg 2). Noting the importance of risk assessment and stress management, the FAA, through the ADM process, acknowledges the role of personal attitudes in decision-making and how those attitudes can influence safety in the cockpit. The FAA also outlined a three-step model to assist pilots with incorporating the process; perceive, process, perform. The model is intended to be applied continuously, throughout the flight. Crew Resource Management (CRM) also evolved out of ADM, as a means of extending ADM beyond the cockpit and including all personnel involved in the flight process, such as crew members.

Despite its initial entrance into regulatory guidance by the FAA nearly thirty years ago, ADM remains a critical component in pilot training, as well as aviation ground operations. Research has shown that ADM can be improved by training (Harris & Li, 2016;) but is also influenced by organizational culture and leadership (Valentin-Marian & Venera, 2016). Additionally, despite regulatory support from the FAA in support of effective ADM training and practices, pilot fatigue has still been found to influence the decision-making process in the cockpit (Ballard, 2014). Since its inception, improvements and recommendations have been made on how best to implement effective ADM practices into the cockpit. However, this process has not been adequately researched or incorporated into aviation maintenance despite recent emphasis on the percentage of accidents due to human error within this environment. Approximately 80% of all major Federal Aviation Regulation (FAR) Part 121 aviation accidents can be attributed to human error, 10% of which are caused by aviation maintenance human error (Marais & Robichaud, 2012). Given its proven track record in improving cockpit safety, ADM could provide an opportunity to improve safety in the aviation maintenance environment.

From the Classroom to the Industry

The best way to teach ADM is to introduce basic concepts of decision-making while putting individuals in situations where they can practice ADM with positive reinforcement for safe judgment and decision-making behaviors (FAA, 1991). Decision-making training must focus on real-world problem solving in which simulation training is an excellent environment for developing decision-making skills (Thomas, 2017). Simulation is recognized in high-risk industries such as aviation for decision-making training as it is very difficult to achieve effective training outside of the normal context decisions are made. In developing decision-making skills, the need is to focus on the use of simulation-based training in highly realistic work-based scenarios. Within high-risk industries, critical decision-making typically occurs in challenging, sub-optimal environments. To develop greater decision-making ability, individuals need exposure to such conditions to build resilience and continue to build non-technical skills. Simulation training provides a psychologically safe environment where effective training can take place (Thomas, 2017).

Simulation training is widely used in aviation, mainly in pilot training. The use of ADM training through simulation with pilots lead to decisions that are less rushed, ill-considered, and overall better decisions are made in terms of situation assessment and risk management (Li & Harris, 2008). Response times are also believed to shorten as further training and practice in ADM through simulation is completed. Within Li and Harris's (2008) study, pilots were found to demonstrate better performance as a result of training in ADM. After each simulator trial, the majority of the pilots who received ADM training applied the most appropriate ADM method for the given situation. In accidents where loss of control was cited as a factor, timely and effective decision-making that did not impede the pilot's cognitive capacity to fly the aircraft may have produced more favorable outcomes possibly avoiding accidents. Despite this sobering consideration, there is no specific requirement for decision-making to be taught in pilot training syllabi (Taylor, Dixon-Hardy & Wright, 2014). The results of decision-making accidents are a product of incomplete data, lack of experience, or biases (Strauch, 2016). Decision-making can be improved by increasing situational awareness of all involved in decisions (Dekker, 2015).

A simulation model that described the flight operations and maintenance of fighter aircraft during normal and conflict conditions in the Finnish Air Force was constructed to help maintenance designers in normal operating conditions allocate appropriate personnel and material resources. The ultimate goal of the simulation training model was to learn how to maximize the conflict time operational capability of the fleet. The model was a valuable aid in improving maintenance-related decision making and found useful for training purposes in classroom demonstrations and field training (Mattila, Virtanen & Raivio, 2008). Overall, the evaluation of ADM training for pilots has found those that received ADM training outperformed those groups that did not. The trained groups had greater gains in risk management performance compared to those that did not receive the training (Li & Harris, 2007). Under conditions of time pressure, decision-makers draw on the training to help determine what is occurring in the current situation, suggesting that if decision-making is required in such circumstances, the practice of tasks under those conditions is necessary (Kaempf & Orasanu, 1997). The simulations foster a better mental directory of scenarios a pilot can draw on in the stressful situations (Stokes & Kite, 1999). A simple, short, cost-effective training program in the use of decision-making produces significant gains in decision-making performance (Li & Harris, 2007). Such training can and should be integrated into current aviation maintenance training through simulation.

Skills acquired by simulation-based training adequately transfer to operative settings (Sturm et al., 2008) with firm scientific evidence of transfer from training in a virtual environment to real-world tasks (Rose et al., 2000). The intensive use of simulators has had a positive impact on commercial aviation safety and is accepted by operators, flight crews, unions, and regulators (Allerton, 2002). Simulation training offers practical training without incurring further risk. Incorporating scenarios through the simulation training allows training to be practiced over and over again providing a template form in which good decisions in various situations are constructed. The use of simulation in this manner is likely more effective than discussions in the classroom (Taylor et al., 2014).

In aviation and many other industries such as medicine and rail, it is understood that simulation training is a valuable teaching method for decision-making. In surveying aviation professors and instructors, the findings indicated the need for ADM instructional methods in flight training and that teaching ADM was not consistently used (Cassens, Young, Greenan, & Brown, 2018). There were significant differences in how ADM instruction specific to good examples of decision-making and allowing students to make go/no go decisions for flights were incorporated into realistic training scenarios and lessons (Cassens et al., 2018). Scenario training was placed at the bottom of professors' and instructors’ priorities indicating the efforts of the FAA encouraging scenario-based education have not been entirely successful (Cassens et al., 2018). The need to expose learners to various situations through simulation allowing them to develop into skilled decision-makers is not being fully optimized. While ADM training has been mostly focused on pilots, the need is also great in aviation maintenance. Few studies have attempted to develop a framework for maintenance optimization through decision-making (Alrabghi & Tiwari, 2016). The need is for decision training within practitioners and academics that implements the simulation models with the available data and consideration of specific contexts (Van Horenbeek, Pintelon, & Muchiri, 2010) for aviation maintenance.

When teaching students about decision-making within complex systems, it is vital to incorporate methods and tools allowing learners to gain explicit and implicit knowledge about complexity and decision-making (Ku, MacDonald, Andersen, Andersen, & Deegan, 2016). Such methods help learners identify where positive, meaningful outcomes can be made through interventions, directly make the interventions, and observe how their actions influence the system they are managing. Simulation-based learning increases intrinsic motivation in students, nurtures the ability to bring concepts and analytic skills together to solve a complex problem, and then change from linear to dynamic thinking (Ku et al., 2016).

Discussion & Conclusions

Recent studies on decision-making training suggest specific training approaches may be most efficient when the decision-maker has had previous experience with similar situations, as is the case with the NDM process. Attempting to cover a breadth of aviation decision-making contexts in a generalized manner is less efficient and may be less effective when decisions are time-critical, as in an aviation maintenance environment. It is also important to emphasize context-based experiences in decision-making training, such as those used in the simulation. Aviation knowledge acquired through training and experience is essential for proper decision making. Aviation professionals must understand that successful decision making does not always involve the choice of the optimum solution. Given time pressures and uncertain conditions, success is making a choice that is sufficient to ensure safety.

In addition to training methods, a reporting system that proactively identifies human error using existing SMS programs would help to create awareness regarding the influence of human factors on aviation maintenance errors. Leveraging existing programs, such as SMS, minimizes the financial burden that often accompanies new procedures. The REPAIRER method appropriately addresses this need by including a human error component to hazard reporting, a method currently employed by aviation maintenance organizations. Leveraging the FAA's well-known PEAR (people, environment, actions, resources) model for human factors, the REPAIRER expands this framework by including the rating and reporting of a hazard, as well as the execution and reevaluation of a mitigation strategy.

R-Report and Rate a human factors hazard
E-Environmental analysis
P-People involved
A-Actions of people identified
I-Investigate procedures
R-Resource evaluation
E-Execute recommended mitigation strategies
R-Reevaluate strategies and adjust

Another opportunity to manage human error in decision making would be during the hiring process. The development of a screening tool that measures risk tolerance would assist hiring managers by identifying those individuals that are too risk-averse or tolerant. High consequence industries require personnel with unique skill sets; those that can make appropriate decisions during times of intense pressure. Additional research is needed, however, to test these theories in an aviation maintenance environment.

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Personality Trends in the Pilot Population

Maria E. Chaparro
Florida Institute of Technology

Meredith Carroll
Florida Institute of Technology

Shem Malmquist
Florida Institute of Technology

Personality has been acknowledged since the 1970's as an influencing factor in pilot performance and training outcomes (King, 2014; Bartram, 1995). Since the late 1940's, pilot selection techniques have included personality related questions (Olson, Walker, & Phillips, 2009; Callister, King, Retzlaff, & Marsh, 1999; Dolgin & Gib, 1988; Fiske, 1947). Unfortunately, despite the large number of different personality indexes used within this line of research, there has not been an aggregation of all aviation studies examining pilot personality and its impact on performance and success. In the current effort, a literature review was conducted to identify research that examined pilot personality traits, and a high-level summary of the findings related to trends in pilot personality traits is provided. The summary includes an examination of personality traits across the differing pilot categories (i.e., commercial, student, and military pilots) and pilot genders. When examining pilots, in general, compared to a general population, consistent with past research, pilots tend to exhibit personality traits lower in neuroticism, higher in extraversion, equivalent in openness, lower in agreeableness, and higher in conscientiousness. However, when different pilot categories are examined, the trends are not as ubiquitous. For instance, commercial pilots research consistently shows pilots to have higher levels of conscientiousness than the general population; however, for military and student pilots the results are not equivocal. We present here the methods and results associated with our review of the literature and provide a discussion of what can be gleaned and future research needed.

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Personality has been acknowledged since the 1970's as a factor that influences pilot performance and training outcomes (King, 2014; Bartram, 1995). Since the late 1940's, pilot selection techniques in both military and commercial settings have included personality assessments (Olson, Walker, & Phillips, 2009; Callister, King, Retzlaff, & Marsh, 1999; Dolgin & Gib, 1988; Fiske, 1947). Although there is a large body of work related to pilot personality, given the disparate goals, measures, pilot types, and findings within the works, there is currently not an overarching understanding of how personality influences pilot performance and success, and if there are indeed personality traits that set pilots apart from the general population.

Much of the research related to personality traits in the pilot population aims to identify a pilot-specific personality profile or pilot-specific personality traits (Ragan, 2010; Yeames, 2001). However, the focus and means by which these questions are examined differ, making it challenging to draw overall conclusions. For example, many studies examining pilot personality focus on the military population (Chapelle, Novy, Sowin, and Thompson, 2010; Ragan 2010; Grice & Katz, 2006). However, pilot personality findings related to this population may differ significantly from the commercial pilot population as military culture has been found to have a profound effect on personality (Jackson, Thoemmes, Jonkmann, Lüdtke, & Trautwein, 2012). There are also studies which have examined pilot-in-training personality traits (Fussell, Dattel, and Mullins, 2018; Robins, Fraley, Roberts, & Trzensniewski, 2001). Research has shown significant changes in personality during young adulthood (Caspi, Roberts, & Shiner, 2005). Additionally, typical pilot-in-training environments are extremely different from commercial operations or military environments, and environment has been found to have a marked effect on personality (Ullén et al., 2012). Pilots-in-training in college go through complex challenges and adaptations as this is usually their first time away from home and the period where they are transitioning to preparedness for marriage and the workforce (Robins, Fraley, Roberts, & Trzesniewski, 2001). Some of the literature examined pilot personality trends of a particular gender or differences between genders. Gender differences have been found in the non-aviation personality literature and previous studies in aviation have not found this same trend (Novello & Youseff, 1974). With growing numbers of female pilots, it is important to understand gender differences of pilots for operational and medical consideration (King, McGlohn, & Retzlaff, 1997).

The goal of this paper is to aggregate the pilot personality research that has been conducted to date, draw conclusions regarding key questions and identify research gaps to guide future research. Of particular interest are the following research questions:

(1) Are pilot's personality traits different from the general population?
(2) Are there differences in the personality traits of commercial, military and pilots-in-training?
(3) Are there differences in the personality traits of female and male pilots?

These questions are the focus of the methods and findings discussed in the following sections.

Methodology

First, a literature review was conducted to identify research which used personality inventories to examine pilot personality traits. Literature was searched utilizing the following databases: Florida Tech Summons library database, ProQuest, Wiley Online Library, PsycINFO, and Google Scholar. The following key words were used: pilot, commercial pilot, military pilot, pilot-in-training, aviation, personality, five-factor model (FFM), gender, Neuroticism, Conscientiousness, Extraversion, Agreeableness, and Openness. The personality traits of focus were those associated with the five-factor model (FFM); however, the literature review revealed several other personality indexes not using the FFM, therefore, these were included in the review as well. When an article was identified, the abstracts were reviewed to determine whether the studies were relevant to the scope of the current study. Study relevancy was determined based on two criteria, including that the study either (a) reported pilots' raw personality scores, or (b) compared pilot personality scores to a general or specific population, (e.g., a working population or pilot-in-training population).

Second, papers deemed relevant were thoroughly reviewed and the following information was extracted and input into a database: the research focus of the article, type of research (theoretical, experimental, etc.), target constructs (e.g. personality), pilot type (e.g., commercial, military or pilot-in-training), the population the sample was compared to, summary of findings, individual difference factors examined (e.g., gender, etc.), study methodology, measures (i.e., NEO-PI-R), type of measures, (e.g., physiological, survey, behavioral), results/findings, limitations, and suggested future research.

Third, the FFM was chosen as the benchmark against which to aggregate findings associated with the range of personality measures used to assess pilot personality. This decision was made due to (1) the FFM being the most commonly used personality index within the database of studies reviewed, and (2) the FFM's prominence in the literature assessing general personality, its validity, and its recurrent use in the pilot personality literature (Fussell, Dattel, & Mullins, 2018; Fitzgibbons, Davis, & Schutte, 2004; Callister et al., 1999), The five traits which are represented in the FFM are: Neuroticism (N), Extraversion (E), Openness to Experience (O), Agreeableness (A), and Conscientiousness (C). Each of the five factors are described in Table 1 per Costa and McCrae (1992).

Table 1
FFM and Descriptions

Facet	Description
Neuroticism	Intensity and frequency of experienced negative emotions, sensitivity to negative aspects of environment
Extraversion	Amount of energy directed outwards to the external environment, and need for external stimulation
Openness	Receptivity to a range of external and internal sources of information and new input
Agreeableness	Role a person adopts in relationships on continuum from compassion to antagonism; likelihood of person taking on board, accepting, and being influenced by perspectives or concerns of others
Conscientiousness	Strength of purpose and drive to goal accomplishment

Fourth, based on the results of studies in the database, a mapping was created for each of the benchmark personality factors (i.e., Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness). Within this mapping, results from each of the studies were classified as indicating that pilots scored higher, lower, or equal to a comparison population. The mapping was also segmented into the type of sample population including whether the sample was pilot-in-training, GA, commercial or military pilots. Initially the mapping only included articles which used a FFM measure. The mapping was then expanded to include findings from studies which utilized measures that have been shown in the literature to correlate with the FFM factors.

Finally, we summarized trends in the data related to the personality traits of: (a) pilots, in general, compared to the general population, (b) commercial vs. military vs. pilots-in-training, and (c) female vs. male pilots. The following sections discuss the resulting findings.

Results

The literature review resulted in 24 publications that met the inclusion criteria. Table 2 summarizes the number of studies with each pilot and comparison populations, and the following paragraphs provide a high level description of the studies various goals and methods.

Table 2
Number of Studies with each Pilot and Comparison Population

Comparison Population	**Pilot Samples**			
	Military	Commercial	Pilots-in-training	Total
General Population	15	3	1	19
Working Population	1	2	0	3
College Students	0	0	2	2
Total	16	5	3	24

The 16 studies which utilized military populations had a range of different objectives and approaches. Chappelle et al. (2010) administered the NEO PI-R to 10,142 USAF-rated pilots with the purposes of (a) providing normative data for USAF female pilot personality traits, (b) investigating differences between USAF female and male pilots, and (c) investigating differences in personality traits between female pilots with various positions. Ragan (2010) administered the NEO PI-R and Multidimensional Aptitude Battery (MAB-II) to 1,819 USAF-rated fighter pilots to update the current literature base with a more representative sample of current USAF pilots. Campbell, Moore, Poythress, and Kennedy (2009) compared 956 U.S. Naval aviators to both the U.S. Air Force (USAF) population and the general population. Several studies surveyed military pilot personality traits using the FFM to investigate whether there was a typical military pilot personality, if gender differences were present, or if there were differences based on stage in their careers (King, Barto, Ree, & Teachout, 2011; Callister et al., 1999; King, Callister, Retzlaff, & McGlohn, 1997; King, McGlohn, & Retzlaff, 1997). Bucky & Speilberger (1973) and Vaernes et al. (1991) as cited in Castaneda (2007), utilized the State-Trait Anxiety Inventory to measure military pilot's personality and the relationship between stress, psychological factors, and health-related factors among military aviators. Grice and Katz (2006 & 2007) and Carretta, et al. (2014) administered personality tests to new military aviators, comparing them to the general population. Yeames (2001) as cited in Castaneda (2007) examined US Army Aviation

Warrant Officer personality traits to determine if specific personality factors afford aviators a greater probability of being promoted in the United States Army. Using the Eysenck Personality Questionnaire-Revised (EPQ-R), Glicksohn, J., & Naor-Ziv, R. (2016) compared Israeli military pilot personality traits to population norms and to data previously collected from participants in other sections of the military population to examine whether there were distinctive personality differences. Meško, Karpljuk, Videmšek, and Podbregar (2009) examined the personality traits of Slovenian military pilots in relation to stress coping strategies utilizing the Big Five Questionnaire (BFQ).

The four studies that were conducted with commercial aviation pilots compared personality traits of a sample of commercial pilots to a general population using differing methods. Fitzgibbons et al. (2004) examined U.S. commercial pilot personality traits and whether there was a commercial pilot personality profile by comparing personality traits of 93 U.S. commercial pilots to the general U.S. population using the NEO-PI-R. Dickens (2014) compared the personality traits of 165 commercial helicopter pilots to the general U.K. population using the Big Five Inventory to determine whether experienced rotary wing pilots had a typical personality type. Mesarosova et al. (2018) compared personality traits of 591 European airline pilots to the general working population using the NEO-PI-R to determine the personality profile of this population. Wakcher, Cross, and Blackman, (2003) as cited in Castaneda (2007) compared the personality traits of 81 current U.S. airline pilots, 137 U.S. airline pilot applicants, and the U.S. general population using the Sixteen Personality Factor Questionnaire (16PF).

The three studies which examined non-military pilot-in-training personality traits also had a range of methods. Robertson and Putnam (2008) compared the personality of aviation pilot-in-trainings at the Aviation Flight Program at a Midwestern U.S. university to the general U.S. population using the Myers Briggs Type Indicator (MBTI) to determine if there is a typical personality type in collegiate aviation programs. Gao and Kong (2016) compared the personality types of 103 pilots-in-training in an Australian collegiate aviation program to that of psychology students. The data on psychology students was raw data from a prior study at the same University by Murray et al., (2009). The instrument they utilized was the Australian Personality Inventory (API), a 50-item instrument measuring the FFM in order to determine the differences in personality between pilots-in-training and non-pilot students and to determine if there existed a typical pilot-in-training personality type. Fussell et al. (2018) examined MBTI scores of aviation students who had completed their first solo flight in a US collegiate flight program in relation to a learning preference scale to assess if personality was a predictor of learning preference.

The following sections summarize the results of the 24 studies, specifically, the trends identified regarding the personality traits of: (a) pilots, in general, compared to the general population, (b) commercial vs. military vs. pilots-in-training, and (c) female vs. male pilots.

Pilots Compared to the General Population. Table 3 presents the trends found when examining results associated with the entire pilot population, including commercial, military, and pilots-in-training when compared to the general population. The studies either employed a measure of the FFM or personality indexes which included a factor that has been shown in the literature to highly correlate with one of the five factors. Table 3 and Figure 1 provide a summary of the percentage (and proportion) of studies which have shown that pilots score either higher, equal to, or lower than the general population on each of the five factors. Trends that represent a majority (>50%) are presented in bold print. The sections that follow provide a summary of these trends for each of the five factors.

Table 3
Trends in FFM Scores of Pilots Compared to General Population

FFM Factors	**Pilots (Across all Categories)**		
	Lower	Equal to	Higher
Neuroticism	**89%** *(17/19)*	11% *(2/19)*	0% *(0/19)*
Extraversion	11% *(2/19)*	11% *(2/19)*	**79%** *(15/19)*
Openness	21% *(4/19)*	**63%** *(12/19)*	16% *(3/19)*
Agreeableness	**63%** *(12/19)*	21% *(4/19)*	16% *(3/19)*
Conscientiousness	5% *(1/18)*	39% *(7/18)*	**56%** *(10/18)*

Note: Bolded numbers indicate majority trends (>50%)

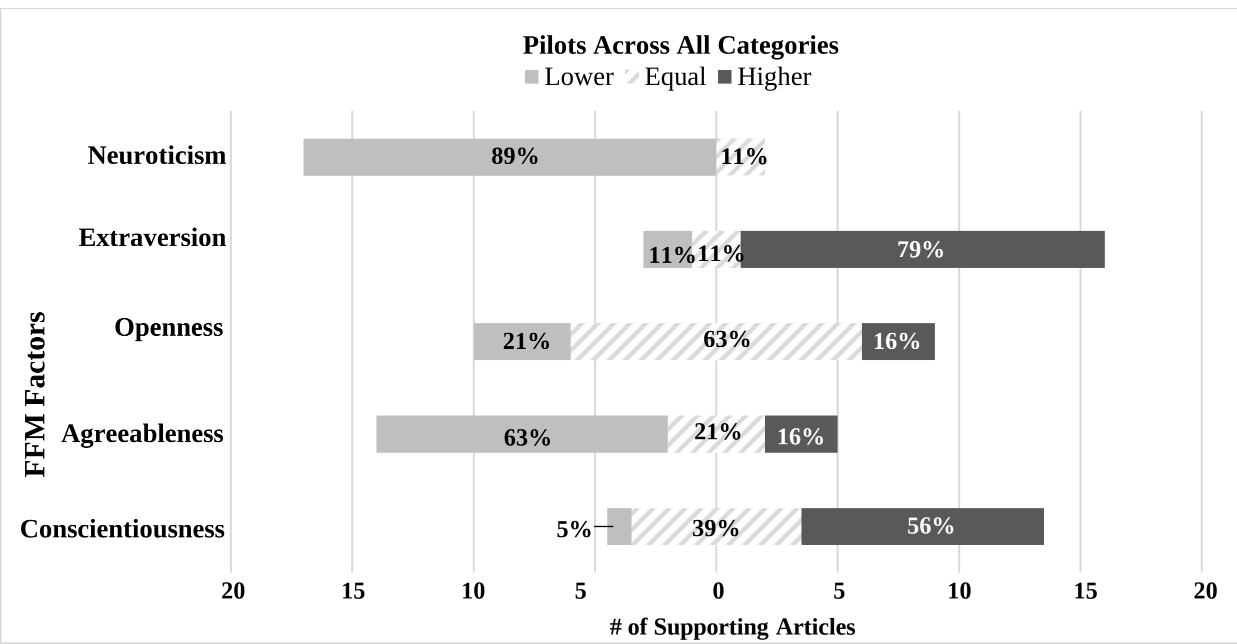

Figure 1. *Trends in FFM Scores of Pilots Compared to General Population*

Neuroticism. The data suggests that pilots typically possess lower levels of Neuroticism than the general population. Seventeen of the 19 studies examining the personality trait of Neuroticism, or a personality trait from a personality index that has shown to be significantly correlated with Neuroticism, reported pilots scores as lower than that of the general population. Fitzgibbons et al., (2004) found that 60% of commercial pilots scored lower than the general population on the Neuroticism factor within the NEO-PI-R, indicating pilots are more emotionally stable than the general population (Fitzgibbons et al., 2004). Additionally, Mesarova et al., (2018) and Dickens (2014) found that commercial pilots scored lower on Neuroticism, as measured by the NEO-PI-R and Big Five Inventory (BFI), when compared to workers in the U.K. and the general U.K. population, respectively. Fifteen studies using measures which target the five factors of personality, found that military aviators scored lower on Neuroticism than the general U.S. population (Glicksohn & Naor-Ziv, 2016; Carretta et al., 2014; King et al., 2011; Chapelle et al., 2010; Ragan 2010; Campbell et al., 2009; Grice & Katz, 2006; Yeames, 2001; King, Callister, Retzlaff, & McGlohn, 1997; King, McGlohn, & Retzlaff, 1997; Vaernes et al. 1991; Bucky & Speilberger, 1973). Only two of the 19 studies that examined pilot scores on Neuroticism or a related dimension, found pilots to be equivalent to the general population on the Neuroticism dimension, both of which were military pilot populations (Grice & Katz, 2007; Callister et al.,1999) and no studies found that pilots scored higher on Neuroticism than a general population.

Extraversion. With respect to Extraversion, the data suggests that the pilot population typically has higher levels of Extraversion compared to the general population. Higher Extraversion was found for pilots in 15 out of the 19 studies that examined Extraversion or a personality trait from a personality index that has shown to be significantly correlated with Extraversion (Carretta et al., 2014; Chappelle et al., 2010; Ragan, 2010; Callister et al., 1999; Yeames, 2001; King, Callister, Retzlaff, & McGlohn, 1997; King, McGlohn, & Retzlaff, 1997). Twelve of these studies compared various military pilot samples to the general population. Additionally, two studies found pilots to be lower on the Extraversion factor. Mesarosova et al. (2018) found that U.K. commercial pilots had lower Extraversion when compared to the U.K. working population. Fussell et al. (2018) found U.S. pilots-in-training to be lower in Extraversion than the general U.S. student population. Two studies also found the populations were equivalent in Extraversion. Grice and Katz (2006) found that a sample of 75 military aviators (i.e., utility attack, scout, and cargo aviators) scored equivalent to the general population on Extraversion. Gao and Kong (2016) also found that pilots-in-training were equivalent to the general student population in terms of Extraversion.

Openness. The data suggest that the pilot population typically possesses equivalent levels of Openness when compared to the general population. Out of the 19 studies which examined the Openness factor, or a personality trait from a personality index that has shown to be significantly correlated with Openness, 12 studies found pilots to be equivalent to the general population (Gao & Kong, 2016; Carretta et al., 2014; Dickens, 2014; King et al., 2011; Chapelle et al., 2010; Ragan 2010; Meško et al., 2009; Grice & Katz, 2007; Wackcher et al., 2003; Yeames, 2001; Callister et al., 1999; King, Callister, Retzlaff, & McGlohn, 1997), nine of which were conducted with military samples. However, four of the 19 studies found pilots to be lower in Openness, one with the military population, one with the pilot-in-training population, and two of which were with the commercial population (Fussell et al., 2018; Fitzgibbons et al., 2004; Mesarosova et al., 2018; Grice & Katz, 2006). Three studies found pilots to be higher on Openness when compared to the general population (Campbell et al., 2009; Robertson & Putnam, 2008; King et al., 1997).

Agreeableness. With respect to Agreeableness, the data suggests that the pilot population typically possesses lower levels of Agreeableness compared to the general population. Out of the nineteen studies that looked at Agreeableness or a personality trait from a personality index shown to be significantly correlated with Agreeableness, 12 studies found that pilots scored lower in Agreeableness than the general population (Fussell et al., 2018; Carretta et al., 2014; King et al., 2011; Chapelle et al., 2010; Ragan 2010; Robertson & Putnam, 2008; Grice & Katz, 2007; Fitzgibbons et al., 2004; Wackcher et al., 2003; Yeames, 2001; Callister et al., 1999; King, Callister, Retzlaff, & McGlohn, 1997). Three studies found that pilots scored higher on Agreeableness than the general population, two of which examined a commercial pilot sample (Mesarosova et al., 2018; Dickens, 2014), and one of which examined a military sample (King, 1997). Four studies found their sample of pilots to be equivalent to the general population with respect to Agreeableness (Gao & Kong, 2016; Campbell et al., 2009; Meško et al., 2009; Grice and Katz, 2006).

Conscientiousness. For the Conscientiousness factor, the pilot population appears to trend higher in Conscientiousness when compared to the general population; however, this was the factor for which there was the least clear trend. Ten of the 18 studies examined Conscientiousness, or a personality trait from a personality index that has shown to be significantly correlated with Conscientiousness, found pilots to have higher levels of Conscientiousness than the general population (Mesarova et al., 2018; Carretta et al., 2014; Dickens, 2014; King, 2011; Campbell et al., 2009; Meško et al., 2009; Fitzgibbons et al., 2004; Wakcher, 2003; Yeames 2001; King et al., 1997. Seven of the 18 studies found pilots to be equivalent to the general population with respect to Conscientiousness, six of which were conducted with the military populations (Chapelle et al., 2010; Ragan, 2010; Grice & Katz, 2006 & 2007; Callister et al., 1999; King, McGlohn, & Retzlaff, 1997; King, Callister, Retzlaff, & McGlohn, 1997) and one within the pilot-in-training population (Gao & Kong, 2016). There was only one study which found pilots scored lower on Conscientiousness compared to the general population: Robertson and Putnam (2008), who utilized the MBTI to assess a sample of 83 pilots-in-training at a Midwestern U.S. university.

Pilot Population Subtypes. Table 4 and Figures 2-4 present the trends found when examining each of the three pilot categories separately (i.e., commercial, military, and pilots-in-training) compared to the general population. This includes a summary of the percentage (and proportion) of studies which have shown that each category of pilot scores either higher, equal to, or lower than the general population on each of the five factors. Trends that represent a majority (>50%) are presented in bold print. The sections that follow provide a summary of these trends for each of the five factors.

Table 4
Trends in FFM Factor Scores of Commercial, Military and Pilot-in-trainings

FFM Factors	Commercial Pilots			Military Pilots			Pilots-in-training		
	Lower	Equal	Higher	Lower	Equal	Higher	Lower	Equal	Higher
Neuroticism	**100%** *(4/4)*	0%	0%	**86%** *(12/14)*	14% *(2/14)*	0%	**100%** *(1/1)*	0%	0%
Extraversion	25% *(1/4)*	0%	**75%** *(3/4)*	0%	7% *(1/13)*	**92%** *(12/13)*	**50%** *(1/2)*	**50%** *(1/2)*	0%
Openness	**50%** *(2/4)*	**50%** *(2/4)*	0%	8% *(1/12)*	**75%** *(9/12)*	17% *(2/12)*	**33%** *(1/3)*	**33%** *(1/3)*	**33%** *(1/3)*
Agreeableness	**50%** *(2/4)*	0%	**50%** *(2/4)*	**67%** *(8/12)*	25% *(3/12)*	8% *(1/12)*	**67%** *(2/3)*	33% *(1/3)*	0%
Conscientiousness	0%	0%	**100%** *(4/4)*	0%	**50%** *(6/12)*	**50%** *(6/12)*	**50%** *(1/2)*	**50%** *(1/2)*	0%

Note: Bolded numbers indicate majority trends (>50%) and comparison is being made to the general population.

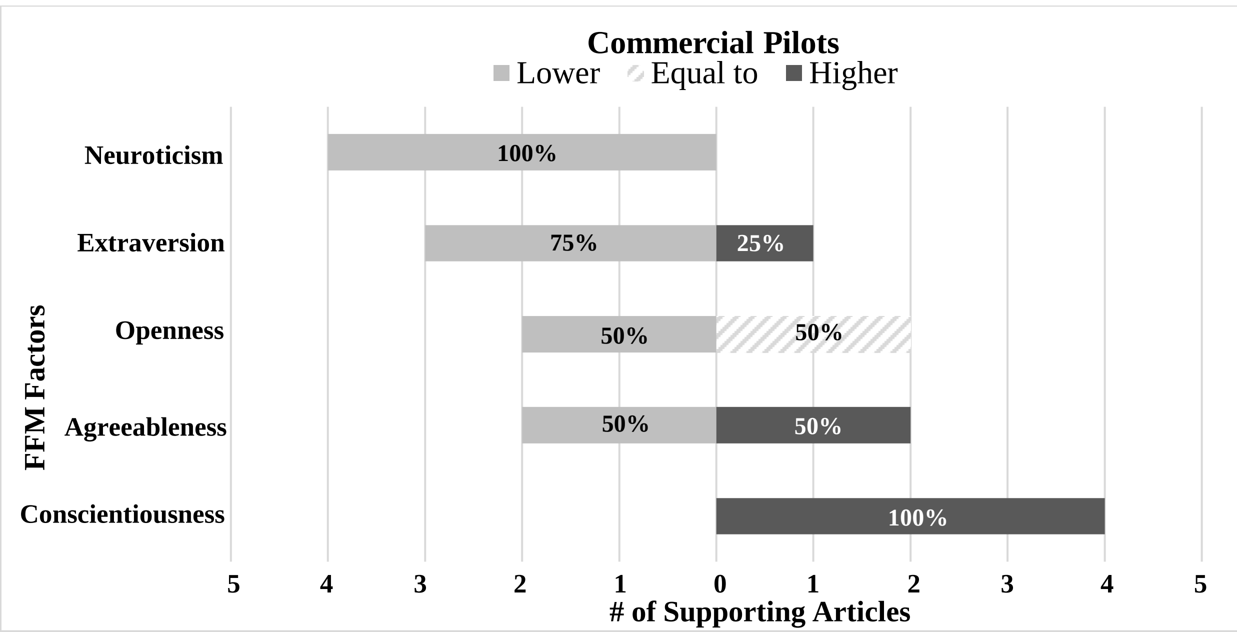

Figure 2. *Trends in FFM Scores of Commercial Pilots Compared to General Population*

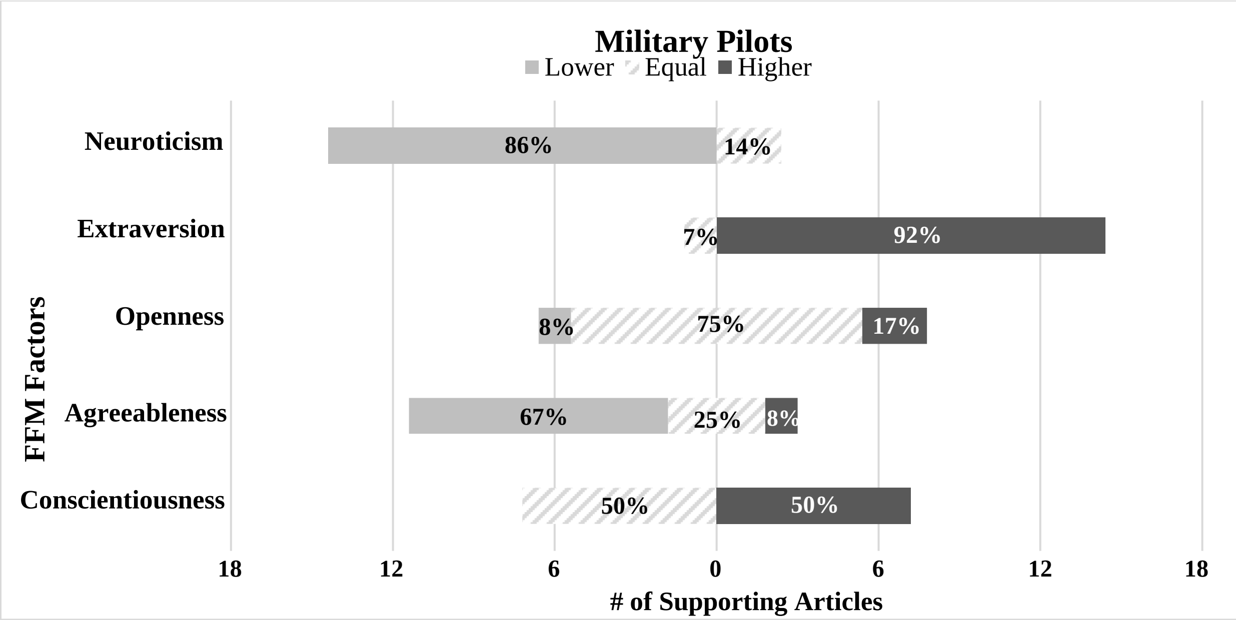

Figure 3. *Trends in FFM Scores of Military Pilots Compared to General Population*

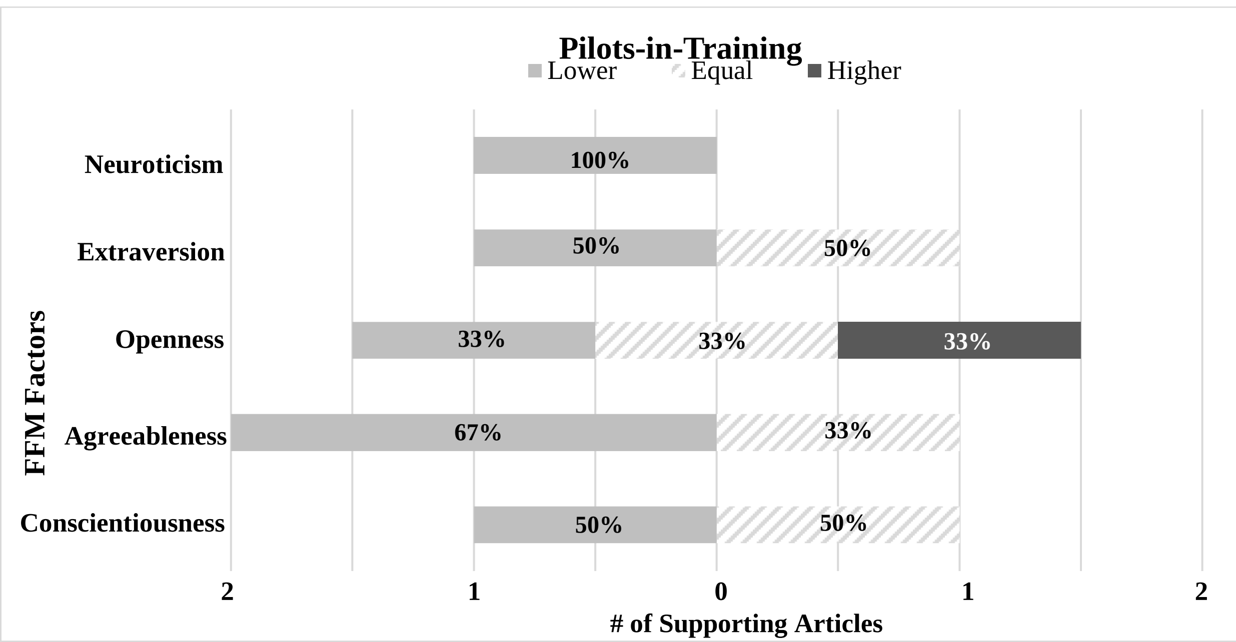

Figure 4. *Trends in FFM Scores of Pilots-in-Training Pilots Compared to General Population*

Neuroticism. With respect to Neuroticism, all three categories of pilots exhibited the same trends with respect to neuroticism. The literature indicated that all categories of pilots typically possess less Neuroticism than the general population.

Extraversion. With respect to Extraversion, while commercial and military pilots typically scored higher in Extraversion, pilots-in-training did not. There were only two studies examining Extraversion within the pilot-in-training population that used measures which correlated to the five factors. One of the studies utilizing the API, showed pilots-in-training as equivalent to the general population (Gao & Kong, 2016) while the other used the MBTI and showed pilots-in-training scoring lower than the general population (Fussell et al., 2018).

Openness. In terms of Openness to experience, military pilots tended to score equivalent to the general population; however, results associated with commercial and pilots-in-training had mixed results. Only two studies concerning military pilots found them to score higher than the population in Openness (Campbell et al., 2009; King et al., 1997). Only one study by Grice and Katz (2006) found that military pilots scored lower than the population in Openness. Two studies on commercial pilots found them to be lower than the general population in Openness (Mesarosova et al., 2018; Fitzgibbons et al., 2004), while the other two found pilots to be equivalent in Openness (Dickens, 2014; Wakcher et al., 2003). When looking at the pilot-in-training population all three studies yielded different results in the domain of Openness, with Gao and Kong (2016) yielding results wherein pilots-in-training were equivalent, Fussell et al., (2018) found pilots-in-training scored lower than the general population, and Robertson and Putnam (2008) had pilots-in-training scoring higher than the general population. Inferences regarding pilots-in-training population are limited as only three studies could be utilized for the pilot-in-training population (Fussell et al., 2018; Gao & Kong, 2016; Robertson & Putnam, 2008).

Agreeableness. With respect to Agreeableness, military pilots and pilots-in-training trended towards lower than the general population; however, results associated with commercial pilots were mixed. Three studies examining the military pilot population found them to be equivalent to the general population (Campbell et al., 2009; Mesko, et al, 2009; Grice & Katz, 2006). One study by King et al., (1997) found that military pilots were more agreeable than the general population. In regards to commercial pilots, two study's findings yielded pilots as scoring lower in Agreeableness than the general population (Fitzgibbons et al., 2004; Wakcher et al., 2003). Two studies found that commercial pilots scored higher than the general population (Mesarova et al., 2018; Dickens, 2014). Two of the studies utilizing the pilot-in-training population found they were lower in Agreeableness than the general population (Fussell et al., 2018; Robertson & Putnam, 2008). Gao and Kong (2016) found pilots-in-training to be equivalent in the Agreeableness factor. Inferences regarding pilots-in-training population are limited as only three studies could be utilized for the pilot-in-training population (Fussell et al., 2018; Gao & Kong, 2016; Robertson & Putnam, 2008).

Conscientiousness. With respect to Conscientiousness, all commercial pilot studies found commercial pilots to be higher in Conscientiousness than the general population (Fitzgibbons et al., 2004; Mesrosova et al., 2018; Dickens, 2014); however, studies utilizing military pilots had mixed results. Six of the twelve studies using military pilots found them to be higher in Conscientiousness while the other six studies found them to be equal in Conscientiousness to the general population. No studies found military pilots to be lower in Conscientiousness. Inferences regarding pilots-in-training population are limited as only two studies could be utilized for the pilot-in-training population (Gao & Kong, 2016; Robertson & Putnam, 2008). However, they found pilots-in-training to be equivalent in one study and lower than the population in terms of Conscientiousness in the other.

Pilot Population Gender Differences

The trends found when examining pilots across two genders (i.e., female and male) are presented in Table 5. The table provides a summary of the percentage (and proportion) of studies which have shown that female pilots score either higher, equal to, or lower than male pilots on each of the five factors. Trends that represent a majority (>50%) are presented in bold print. The sections that follow provide a summary of these trends for each of the five factors.

Table 5
Trends in FFM Factor Scores of Female Pilots Compared to Male Pilots

FFM Factors	Female Pilots		
	Lower	Equal	Higher
Neuroticism	0%	**80%** *(4/5)*	20% *(1/5)*
Extraversion	0%	**100%** *(5/5)*	0%
Openness	0%	20% *(1/5)*	**80%** *(4/5)*
Agreeableness	0%	**60%** *(3/5)*	40% *(2/5)*
Conscientiousness	0%	**100%** *(5/5)*	0%

Note: Bolded numbers indicate majority trends (>50%)

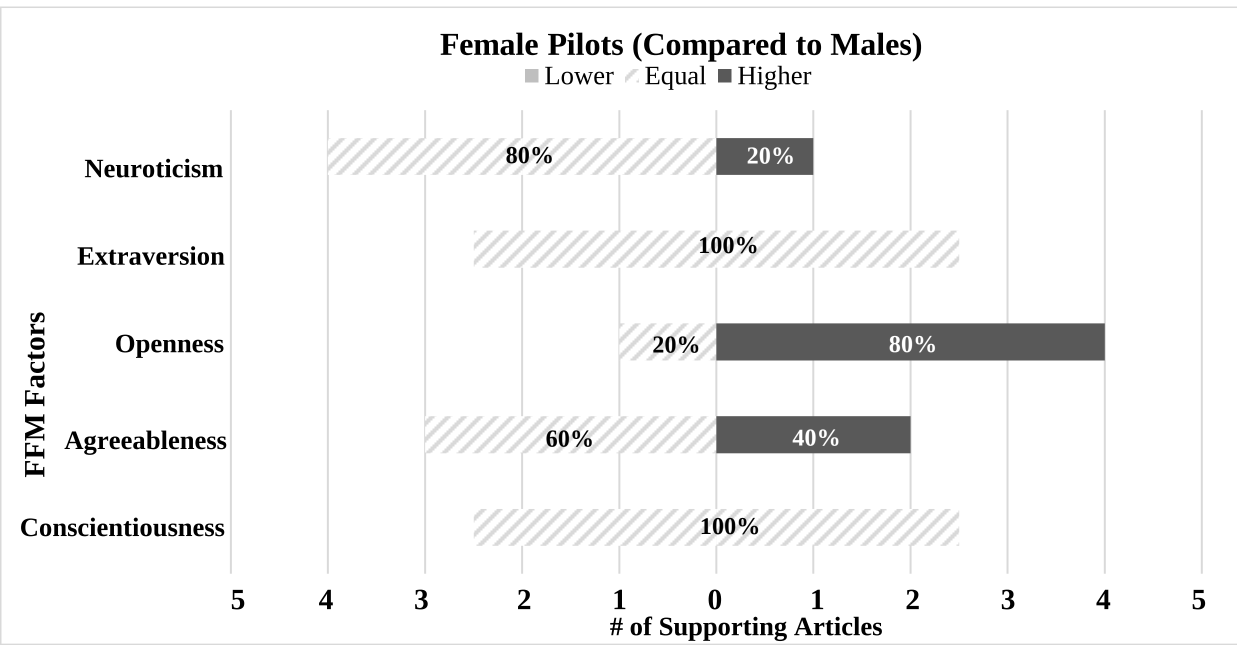

Figure 5. *Trends in FFM Scores of Female Pilots Compared to Male Pilots*

Gender. The results of the pilot comparison table for gender suggests that female pilots have very similar personality traits to that of their male counterparts. Of the five studies which compared personality traits of male and female pilots, personality traits were typically equivalent for four of the five factors, including Neuroticism, Extraversion, Agreeableness and

Conscientiousness. For Agreeableness, there were studies that found females to be both more and less agreeable than males. For Openness, four of the five studies found female pilots to possess higher levels of Openness than males (King et al., 2011; Chapelle et al., 2010; Musson et al., 2004; Callister, 1999; King et al., 1997).

Discussion

When looking at the pilot population compared to the general population, the trend that emerged is lower Neuroticism, higher Extraversion, equivalent Openness, lower Agreeableness, and higher Conscientiousness. When pilots were separated into commercial, pilot-in-training, and military, the trends were slightly different. The only consistent finding across all pilot categories was with respect to Neuroticism, which trended towards lower than the comparison populations. In terms of Extraversion, commercial and military pilots tended to be higher than their comparison populations while in the student population, the two studies found them to be equal or lower in Extraversion. In terms of the Openness factor, commercial and pilots-in-training yielded mixed results, while military pilots tended towards equivalence with the general population. With respect to the Agreeableness factor, commercial pilots had mixed results with two studies finding them lower than the general population and another two finding them higher than the general population. However, military and pilots-in-training trended towards lower in Agreeableness. Finally, when examining the Conscientiousness factor, commercial pilots scored higher in all studies on Conscientiousness, while mixed results were found for the military and pilot-in-training populations. Half of the military studies found pilots to be higher and the other half equivalent in the factor. Pilots-in-training were found to be lower or equal to their comparison populations in Conscientiousness. When looking at the difference in personality factors among genders, females and males were equivalent in all factors except Openness to experience, for which females trended higher.

Low Neuroticism was the most consistent trend found in the studies, with 17 of 19 studies examining Neuroticism finding pilots were lower in Neuroticism than the general population. Neuroticism is associated with anxiety, sensitivity, anger, irritability, and insecurity, among other emotions (Helton & Street, 1992; Barrick & Mount, 1991). Low levels of Neuroticism are associated with calmness, even-temperedness, and the ability to easily deal with stress (Castaneda, 2007). The finding that pilots tend to be low in Neuroticism could be due to the need to be more emotionally stable and less reactive to stress as aviation is a high stakes/high stress environment (Fitzgibbons et al., 2004). Therefore, individuals with low Neuroticism and high emotional stability may be drawn to the aviation industry and succeed/persist as they are better able to handle the stress (Campbell et al., 2009). Individuals who score high in Neuroticism can become easily anxious and potentially struggle in an environment with high stress and stakes (Cooper, 2015). This finding is consistent with the extant literature and indicates that including Neuroticism in the pilot selection battery may lead to more effective pilot selection (Hormann & Maschke, 1996; Ramachandran, Wadhawan, Kumar, Chandramohan, 1983; Jessup & Jessup, 1971).

With respect to Extraversion, our findings indicate that military and commercial pilots are higher in Extraversion than the general population. High Extraversion, is related to sociability, gregariousness, impulsivity, and an action orientation (Goeters, Timmermann, &

Maschke, 1993). Furthermore, past studies have found that Extraversion is positively related to pilot training success in military aviators (Chang et al., 2018; Campbell, 2009). Given the requirement for military pilots to, at times, be able to depart on a moment's notice, the activeness and impulsivity associated with Extraversion would be beneficial in this career choice. Sociability is of importance to the commercial pilot domain in which pilots are continually performing in a team context (Fitzgibbons et al, 2004). Commercial pilots must communicate effectively over the radio to other individuals, socialize with continually changing co-pilots with whom they may be confined on the flight deck for over 24 hours, and travel to new places where communication is required to operate. When looking at pilot-in-training Extraversion, the trend is different. However, due to the presence of only two pilot-in-training studies this interpretation should be accepted with caution. The current study found mixed results with respect to pilots-in-training extraversion levels, which was typically found to be equivalent to or lower than the general student population. This is not surprising as pilots-in-training are in a very different environment than commercial and military pilots. Pilots-in-training must not only succeed in their flight program, but additionally in their college courses to attain their degree. A study by Schurer, Kassenboehmer, and Leung (2015) found that low levels of Extraversion strongly predicted the probability of obtaining a university degree. This may be due to the need to be more focused on the long-term goals (i.e., degree attainment) rather than impulsivity or action orientation. Additionally, although socializing with peers is an important aspect to success in the university, there is a limit, and too much socialization can be detrimental (Schurer et al., 2015). Therefore, due to their university environment, pilots-in-training Extraversion levels may be different than those of the typical military and commercial pilots. Further, the difference may stem from the period of time in the students life, wherein they are young adults, a time when many changes in personality occur (Lüdtke, Trautwein, & Husemann, 2009; Caspi et al., 2005).

The results related to the Openness domain show no clear pattern in commercial and pilots-in-training; however, in the military domain pilots trended towards equivalence with the general population. These findings suggest that this may not be a facet that differentiates pilots from the general population. This may be due to the highly proceduralized nature of piloting. That is, there are clear checklists and rules that have to be mandatorily followed before, during, and after flight by the crew (Schwaitzberg et al., 2009; Rockliff, 2003). Therefore, there may be less need for a pilot to be adaptive to changes and creative, on a day-to-day basis as the regulators create the terms in which pilots can operate (Rockliff, 2003). Additionally, a common trait associated with Openness is the yearning to move up in position and move around between different job opportunities (Nieß & Zacher, 2015). Given the limited variability in types of jobs available to pilots (e.g., other than flying different types of aircraft), those high in openness may be less drawn to this career.

With respect to agreeableness, when looking at pilots in general, they tended to be less agreeable. This could be due to pilots' need to prioritize performance and goals at hand rather than relationships (Grice and Katz, 2006). However, commercial pilots tended to be more agreeable than the general population in two of the four commercial pilot studies. This trend was not found in military and pilot-in-training categories. Agreeableness is related to traits such as warmth, sympathy, altruism, cooperation, courtesy, flexibility, and having a disposition toward interpersonal trust and consideration of others (Helton & Street, 1992; Barrick & Mount, 1991; McCrae & Costa, 1986). Agreeableness is also an important personality facet in team settings as more agreeable individuals tend to work cooperatively and are better able to resolve conflict (Morgeson, Reider, & Campion, 2005). Agreeableness is also closely tied to trust (Mooradian, Renzl, & Matzler, 2006). Agreeableness in commercial pilots may be due to the constant change in a commercial pilot's crew requiring commercial pilots to be trusting of their crew and straightforward with their needs (Civil Aviation Authority, 2014). However, in the other two commercial studies, as well as most of the military and pilot-in-training studies, pilots were found to be lower in Agreeableness. Low Agreeableness is associated with less empathetic and co-operative attributes (Driskell, Goodwin, Salas, & O'Shea, 2006). Pilots, specifically military pilots, may be less agreeable due to being more concerned with aspects of mission performance over relationships (Grice & Katz, 2006).

With respect to Conscientiousness, the current study found a mix of studies that report pilots being higher or equal to the general population in Conscientiousness. The Conscientiousness factor is related to purpose, mindfulness and drive to accomplish goals, which is extremely important in the military domain (Siem & Murray, 1997) and may be less so in commercial and pilot-in-training domains. Studies on the Conscientiousness domain have found that much of the variance in Conscientiousness is attributable to environmental influences, such as environments that foster or allow the trait to be expressed (Roberts, Lejuez, Krueger, Richards, & Hill, 2014; Krueger & Johnson, 2008). A great example of this is the military population. The military works to break down civilian identity and mold recruits towards the desired military identity (Jackson et al., 2012; Roberts, Wood, & Caspi, 2008). Differences in the sample's military environment across studies may have led to the equivocal results within the military samples. For example, some military training programs may foster more teamwork whereas other sectors may be less focused on this aspect (i.e., single-pilot vs. multi-pilot operations). Interestingly, Air Force pilots have rated conscientiousness as the most important aspect of personality (Siem & Murray, 1997). Conscientiousness is important for working well and thoroughly. The findings that pilots-in-training are lower in Conscientiousness may be due to their age. Contrary to popular belief, personality can change over time (Corker, Oswald, & Donnellan, 2011; Caspi et al., 2005). One period with emotional intense growth is young adulthood, which aligns with the time period in college. Conscientiousness is relevant to many changes during this time period, such as impulse control, which facilitates task- and goal-directed behavior, such as thinking before acting, delaying gratification, following norms and rules (Corker et al., 2011). College students have recently just left home and are being presented with multiple options and trying to find their own way, and learning to prioritize, test rules, andwork through impulsivity.

When looking at the gender differences in pilots, it appears that the differences typically found between genders in the general population are not present within the aviation domain. When looking at gender in the general population, studies have found that women, across most nations typically have higher levels of Neuroticism, Extraversion, Agreeableness, and Conscientiousness than men (Chapman, Duberstein, Sörensen, & Lyness, 2007). However, the only factor in our analysis which seemed to differentiate female pilots from male pilots, is that female pilots tend to be more open to experience than male pilots. This suggests that female pilots may be more receptive to input from other individuals and sources of information than their male counterparts (Costa & McCrae, 1992). Another facet of those high in Openness to experience is related to adaptability (Escolas, Ray, & Escolas, 2016). Female pilots have been found to have less accidents than their male counterparts, even those with more experience (Walton & Politano, 2016). This may be due to their ability to adapt to novel situations. Another plausible reason is that women with this personality type may be more attracted to the aviation domain due to it being amore adventurous occupation not typical for most women. Additionally, women tend to be higher in neuroticism, therefore the typical female personality may not be attracted to the high-stakes and potential risks associated with a piloting career while those who are low in neuroticism do not see it as a high-stakes career. Additionally, similarities between male and female pilots may be due to environmental factors. The piloting job requires that the individuals spend a large amount of time with their fellow co-pilots, which is unlike work environments that women typically find themselves, wherein the individual spends eight hours at work and then goes home to their family every weekday (Roberts et al., 2008; Novello & Youssef, 1974). Given this, female pilot personalities are shaped to a larger degree, by their colleagues and work environment, than is typical for most females in the work force (Roberts et al., 2008).

There are several practical implications of this research. First, it provides insight into personality traits that may be necessary to achieve a successful piloting career. There was a clear difference between pilot-in-training and commercial pilot personality, especially with respect to Conscientiousness. Commercial pilots were found to be high in Conscientiousness whereas pilots-in-training were found to be equal or lower than the general population. This finding could elude to the fact that high levels of Conscientiousness are needed to succeed as a commercial pilot, or that conscientiousness is developed as a pilot’s career progresses. This is consistent with the literature that has found conscientiousness to correlate with successful job performance (Halim, Zainal, Khairudin, Shahrazad, Nasir, & Fatimah, 2011). Therefore, looking into environmental aspects which promote Conscientiousness in the classroom could be a helpful tool to foster pilots-in-training. As stated earlier, this also may be a facet of age, that is, students entering a collegiate aviation program are in an age where they are just learning how to be self-sufficient and their Conscientiousness is developing (Roberts et al., 2008). Commercial pilots also trended towards more extraverted than the general population compared to pilots-in-training who trended towards equal/lower Extraversion. This may elude to an environmental change occurring between training and commercial, that is as pilots-in-training spend time in a commercial setting they become more extraverted. Interestingly, some studies have pointed to college students who score lower in Extraversion being more likely to have successful program completion (Schurer et al., 2015; Lunderberg, 2013). Therefore, collegiate aviation programs may not need to be concerned with students who are lower in extraversion, however, they should provide opportunities for them to exercise traits associated with extraversion. This could be done by collegiate aviation programs encouraging pilots-in-training to get involved in extracurricular activities such as aviation groups to help cultivate more Extraversion. Given the current study’s findings, successful pilots seem to be low in neuroticism. Low neuroticism may therefore be both a good predictor of success and selection parameter for pilots. The literature lends support as low neuroticism has been found to be positively related to performance in jobs involving interpersonal interactions (Mount, Barrick, & Stewart, 1998) and success in commercial and military pilots. Personality may also be a parameter to consider in pilot training to aid in improving pilot success (i.e., training completion). Understanding the personality of pilots in training may provide instructors with a way to adapt their instructional techniques for individual trainees or students. For example, the results of personality assessments could be used to individualize the learning context, such as in the case that an instructor encounters a pilots-in-training who is very low in extraversion, he can provide problem-based training which encourages the trainee to be assertive, or group work that provides the opportunity for them to take the lead. Finally, diversity in personality could be beneficial in performance (Van Knippenberg & Schippers, 2007; Neuman, Wagner, & Christiansen, 1999; Mount, Barrick, & Stewart, 1998) and used as a tool to improve CRM. A study by Neuman et al. (1999) found that differing levels of extraversion and emotional stability (neuroticism) were positively related to team performance. Additionally, a study by Gorla and Lam (2004) found that differing personality types between leaders and personnel lended itself to better team performance. Therefore, differing personality types may work better than a homogeneous pilot type.

Generalizability & Limitations.

The current review is limited in its generalizations due to the limited publications and unequal amount of publications per category. There was more than three times the number of studies on military personality compared to the student and commercial populations. An understanding of the commercial and student population personality traits will be limited until more research is conducted in this area. Therefore, the results need to be interpreted with caution. Additionally, some of the studies utilized measures that were categorized as proxy measures of the FFM factors given their factor correlations with the FFM factors. This allowed us to include a greater number of studies, but may have introduced slight confounds. Finally, some of the trends were based off of only two studies (e.g., two studies pointing towards high than equivalent), which limits the generalizability of the findings.

Conclusion

The goal of this paper was to amass the pilot personality research that has been conducted to date in order to draw conclusions regarding whether (1) pilot's personality traits are different from the general population; (2) there are differences in the personality traits of commercial, military and pilots-in-training, (3) there are differences in the personality traits of female and male pilots. In regards to the first question there are clear differences in pilot levels of Neuroticism, Extraversion, Agreeableness and Conscientiousness, compared to the general population. With regards to our second question, there appear to be differences in personality traits across military, commercial and pilot-in-training population; however, inferences should be interpreted with caution due to the limited number of studies involving commercial and pilots-in-training. The final, question regarding the differences in gender, points to female and male pilots having equivalent personality in all factors except Openness to experience.

Further research should focus on increasing the number of studies examining pilot personality in student and commercial pilot populations using the FFM. Such research could help build an understanding of personality trends that could aid companies and flight training programs in tailoring their training and operations in a way that supports individual success. Further, examining the environmental factors that differ between military and commercial pilot training and operations may help to shed light on how these differences emerge and whether they are due to environmental factors or whether certain personality types are drawn to the different types of pilot operations. Finally, future research should examine the differences in personality trends between female pilots and females in the general population, to determine whether females with a certain personality are drawn to the aviation field or whether they are similar to the female population and over time their personality is shaped by the aviation environment.

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University Aviation Association
2787 N. 2nd St.
Memphis, TN 38127
(901) 563-0505
hello@uaa.aero